REPORT NO. 863-4-14930
DOCUMENT CONTROL NO. DC - 3143

TURBINE POWER CONTROL VALVE ACTUATION SYSTEM [U]

MODEL NT-B4

PART NUMBER 2775004 - SERIAL NUMBER 8

TEST DATA AND RESULTS

(NASA-CR-136923) PERFORMANCE CHARACTERISTICS OF A TURBINE POWER CONTROL VALVE ACTUATION SYSTEM (Bendix Corp.) 50 p
N74-73163
Unclas
00/99 33798
(CODE)
(NASA CR OR TMX OR AD NUMBER)
(CATEGORY)

THE BENDIX CORPORATION
BENDIX PRODUCTS AEROSPACE DIVISION
SOUTH BEND 20, INDIANA

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
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C66-3105

Contract No. NP-2
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Report No. BPAD 863-4-14930
Document Control No. DC-3143

PERFORMANCE CHARACTERISTICS OF A TURBINE POWER CONTROL VALVE ACTUATION SYSTEM - (U)

BENDIX MODEL NO. NT-B4
P/N 2775004, S/N 8

May 1963

Submitted to

Aerojet - General Corporation
Azusa, California

Prepared by

Aerospace Nuclear & Pneumatic Controls Dept.
Bendix Products Aerospace Division
South Bend 20, Indiana

Prepared Under the Direction of: A. J. Wetzel

A. J. Wetzel, Project Supervisor

Approved by: D. J. Schaffer

D. J. Schaffer, Manager
Aerospace Nuclear and Pneumatic Controls Engineering

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SECTION 1

SUMMARY

This report presents the results of the tests performed to evaluate the Turbine Power Control Valve Actuator, Model NT-B4, Part Number 2775004, Serial Number 8. All tests were conducted at the Bendix Products Aerospace Division, South Bend, Indiana, during the period from March through April 8, 1963. After testing was completed, this unit was shipped to the Aerojet-General Corporation on April 9, 1963.

The testing included component evaluation tests, actuator performance tests at room temperature, actuator performance tests at low temperature, and a final calibration before shipment.

Reproductions of actual actuator test data are included in this report. System dynamic-performance data were taken using gaseous hydrogen.

Figure 1-1 shows the actuator with the cover removed.

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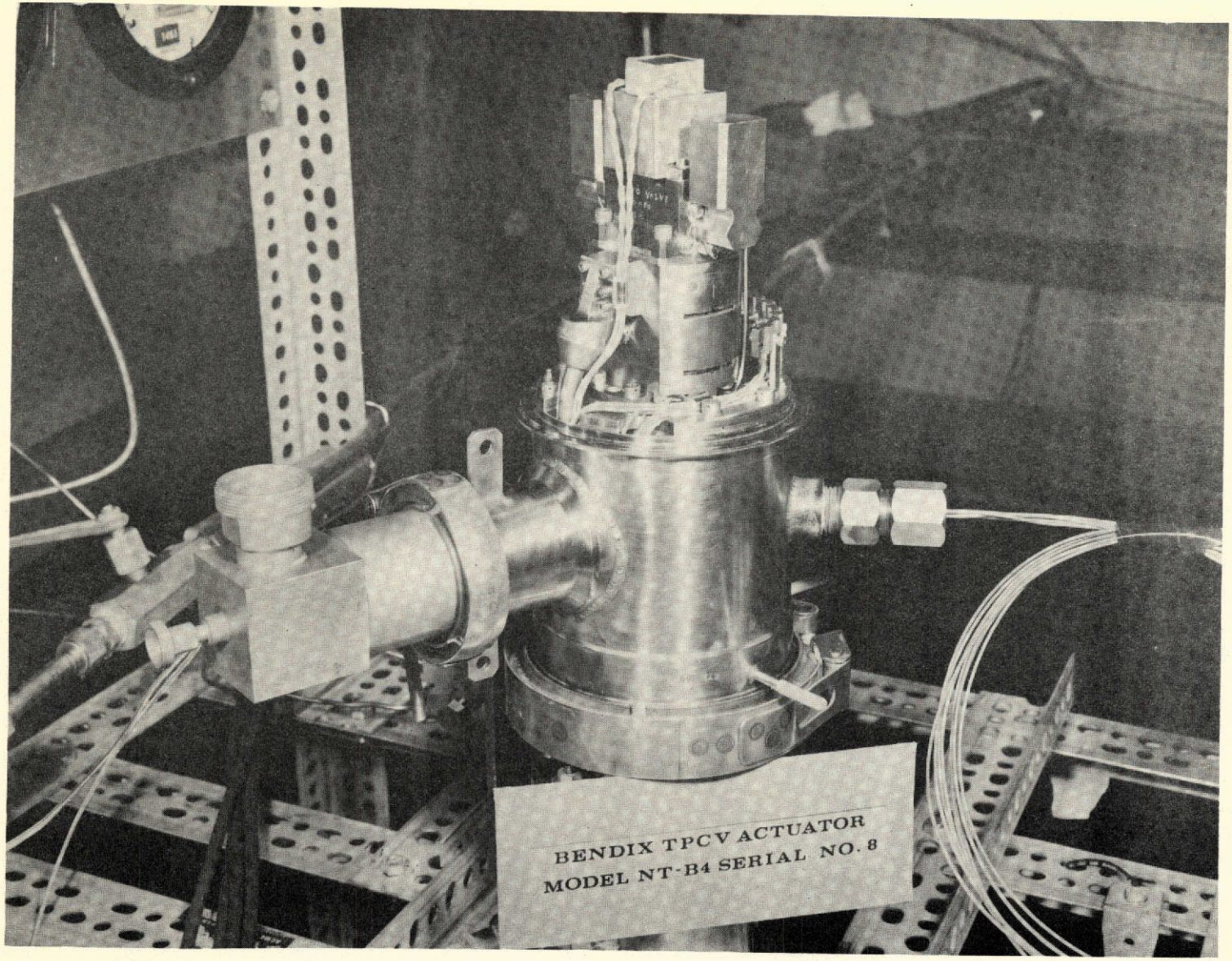

Figure 1-1. Turbine Power Control Valve Actuator, Model NT-B4, S/N 8

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SECTION 2

COMPONENT TEST RESULTS

2.1 MAGNETIC AMPLIFIER

(Part Number 179818-1, Serial Number 3)

A schematic diagram of the magnetic amplifier is shown in Figure 2-1. Figure 2-2 shows the circuit board layout and Figure 2-3 is a plot of amplifier gain.

2.2 TORQUE MOTOR

(Part Number 2151818, Serial Number 106)

Two curves of torque motor characteristics are presented:

a. Figure 2-4. Displacement Sensitivity.

b. Figure 2-5. Frequency Response.

2.3 TORQUE MOTOR - SERVO VALVE

(Servo Valve, Part Number 2775021, Serial Number 6)

Figure 2-6 shows dead ended pressure sensitivity of the servo valve - torque motor combination.

2.4 GEAR MOTOR

(Part Number 2151806, Serial Number 5)

Two curves of gear motor characteristics are presented:

a. Figure 2-7. Torque-Speed-Flow Characteristics.

b. Figure 2-8. Stall Torque-Flow-Pressure Characteristics.

2.5 TORQUE MOTOR - SERVO VALVE - GEAR MOTOR

Five curves of torque motor - servo valve - gear motor characteristics are presented:

a. Figure 2-9. Pressure Sensitivity.

b. Figure 2-10. Stall Torque Characteristics.

c. Figure 2-11. Flow Characteristics.

d. Figure 2-12. No-Load Speed Characteristics.

e. Figure 2-13. Frequency Response.

Figure 2-14 shows the torque motor - servo valve - gear motor combination as mounted on the actuator.

2.6 TRANSMISSION

(Part Number 2775005, Serial Number 1)

The NT-B4 transmission is the same as the NT-B3 transmission except that the double-row output bearings of the NT-B3 have been replaced with a pair of single-row angular-contact bearings. This was done to improve the thrust load capabilities of the NT-B4 actuator and to reduce the amount of output shaft runout.

Following is a listing of significant characteristics of the Serial Number 1 transmission:

Efficiency (lubricated)	88%
Efficiency (not lubricated) @ 370 in-lb torque	85.8%
Efficiency (not lubricated) @ 740 in-lb torque	78%
Break-out torque	1-2 in-oz
Backlash	(not measurable)
Stiffness from 0 to 200 in-lb	60,700 in-lb/radian

2.7 POTENTIOMETER

(Part Number 2151097)

Feedback Potentiometer - S/N 2F4650, Position-Indicating - S/N 2F4656

(These potentiometers are Markite Type 8038)

Potentiometer settings were made in accordance with Figure 2-15.

2.8 INLET AND OUTLET CONNECTOR ASSEMBLY

(Part Number 2775384)

Figure 2-16 shows the re-designed inlet and outlet connector assembly which was shipped with this actuator, and will be part of all other NT-B4 actuators still to be shipped. Vibration tests conducted with the Model NT-B3 actuator indicated some possible trouble areas with the previous design.

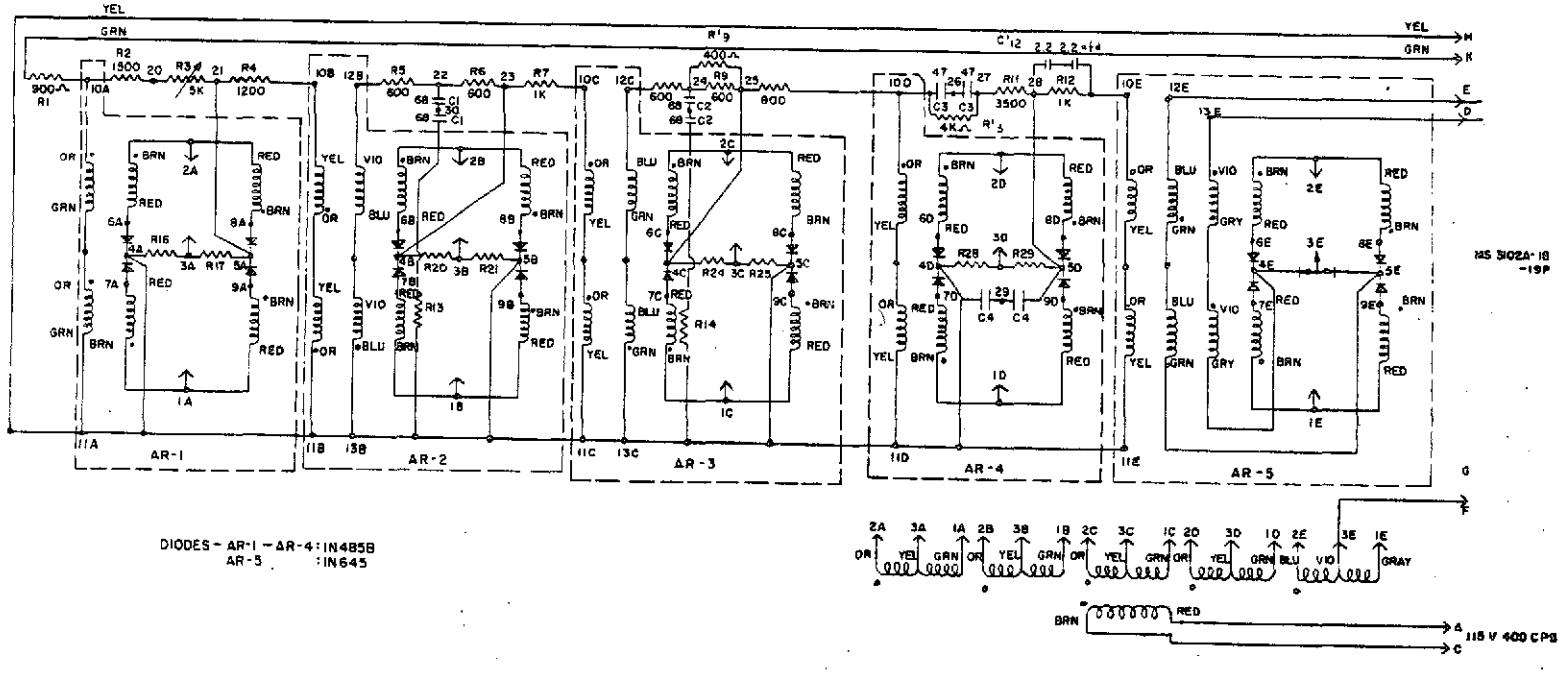

Figure 2-1. Schematic Diagram - Magnetic Amplifier, P/N 179818, S/N 3

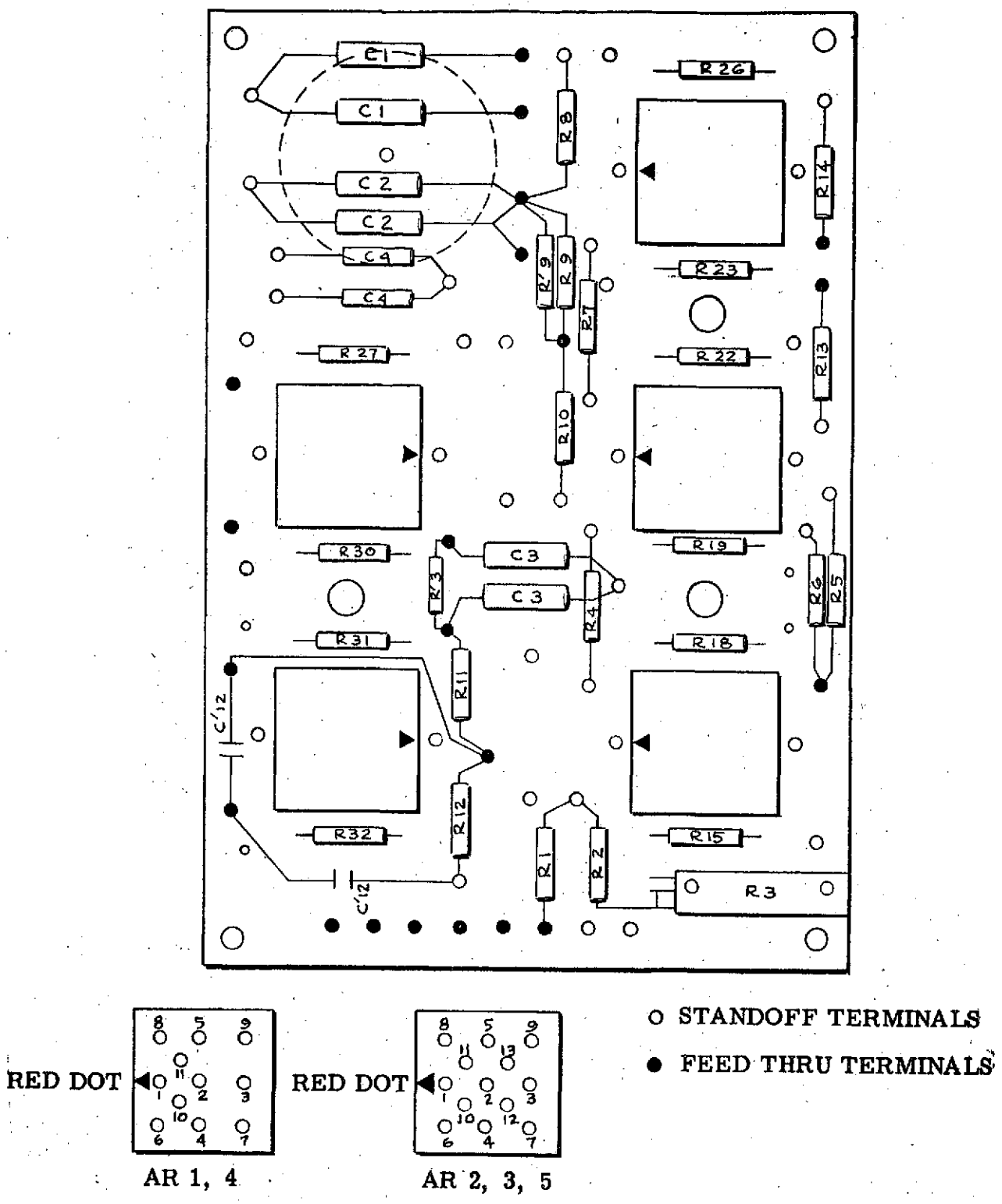

Figure 2-2. Circuit Board Layout Amplifier, P/N 179818, S/N 3

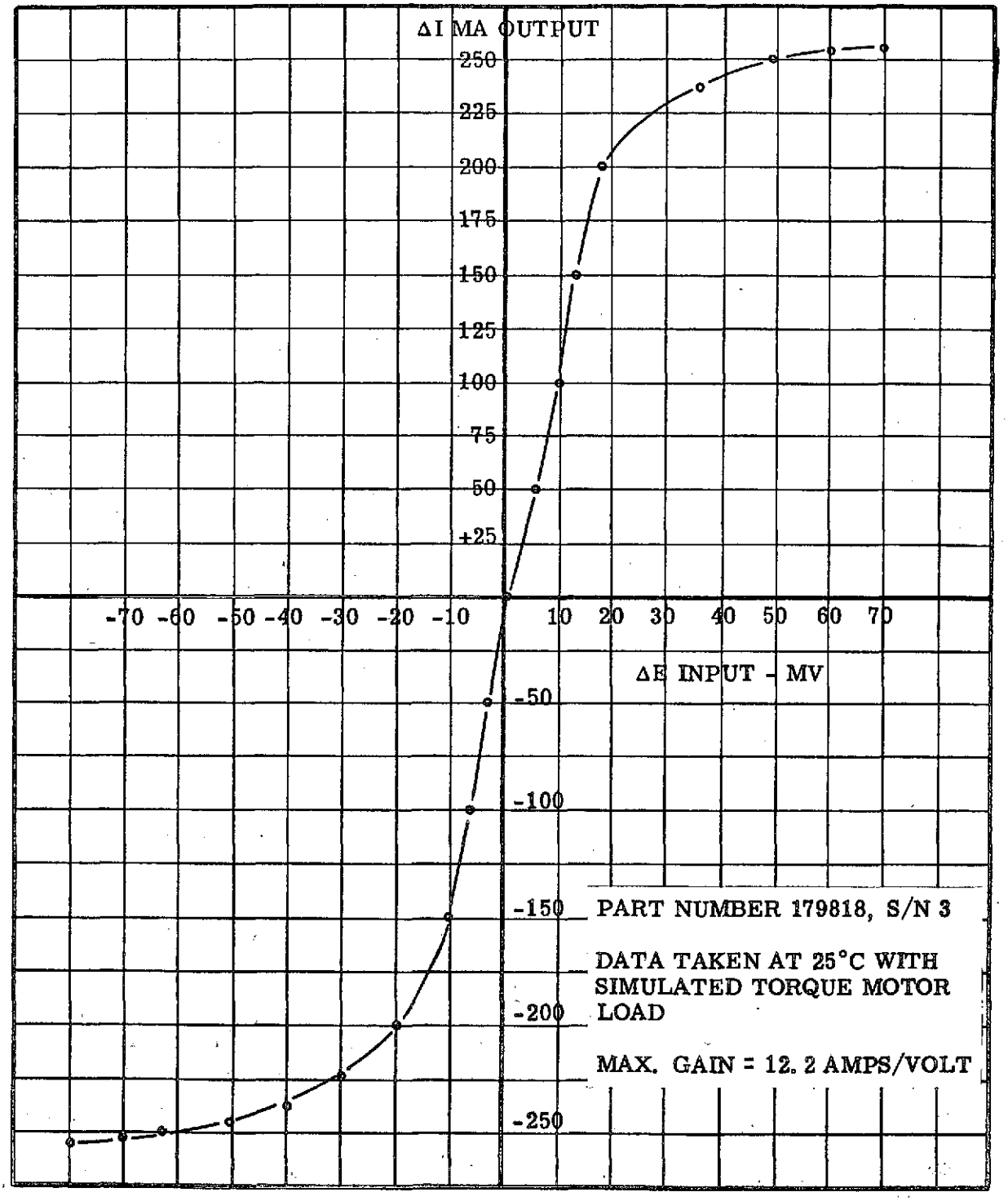

Figure 2-3. Amplifier Gain Before System Compensation

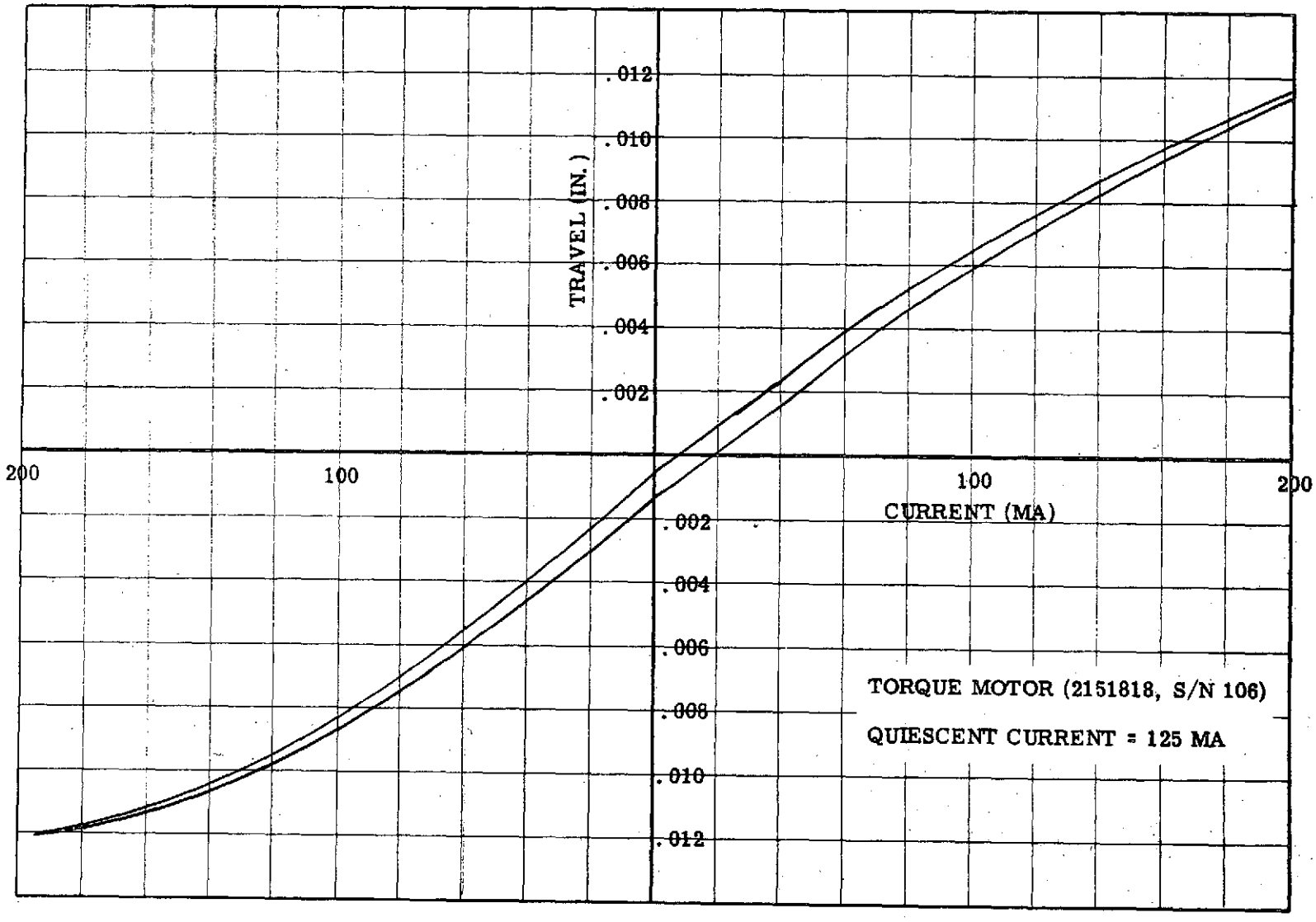

Figure 2-4. Torque Motor Displacement Sensitivity

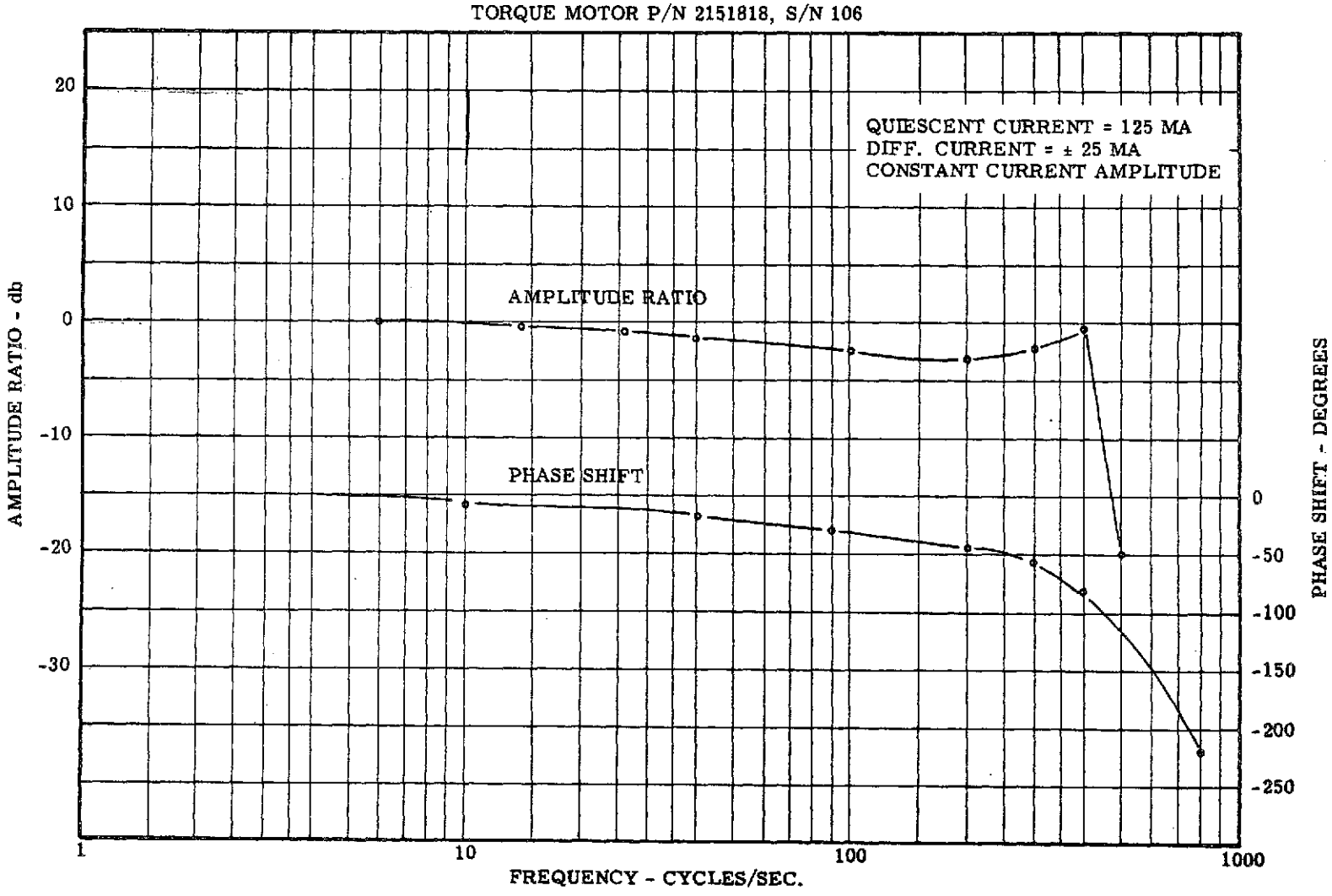

Figure 2-5. Torque Motor Frequency Response

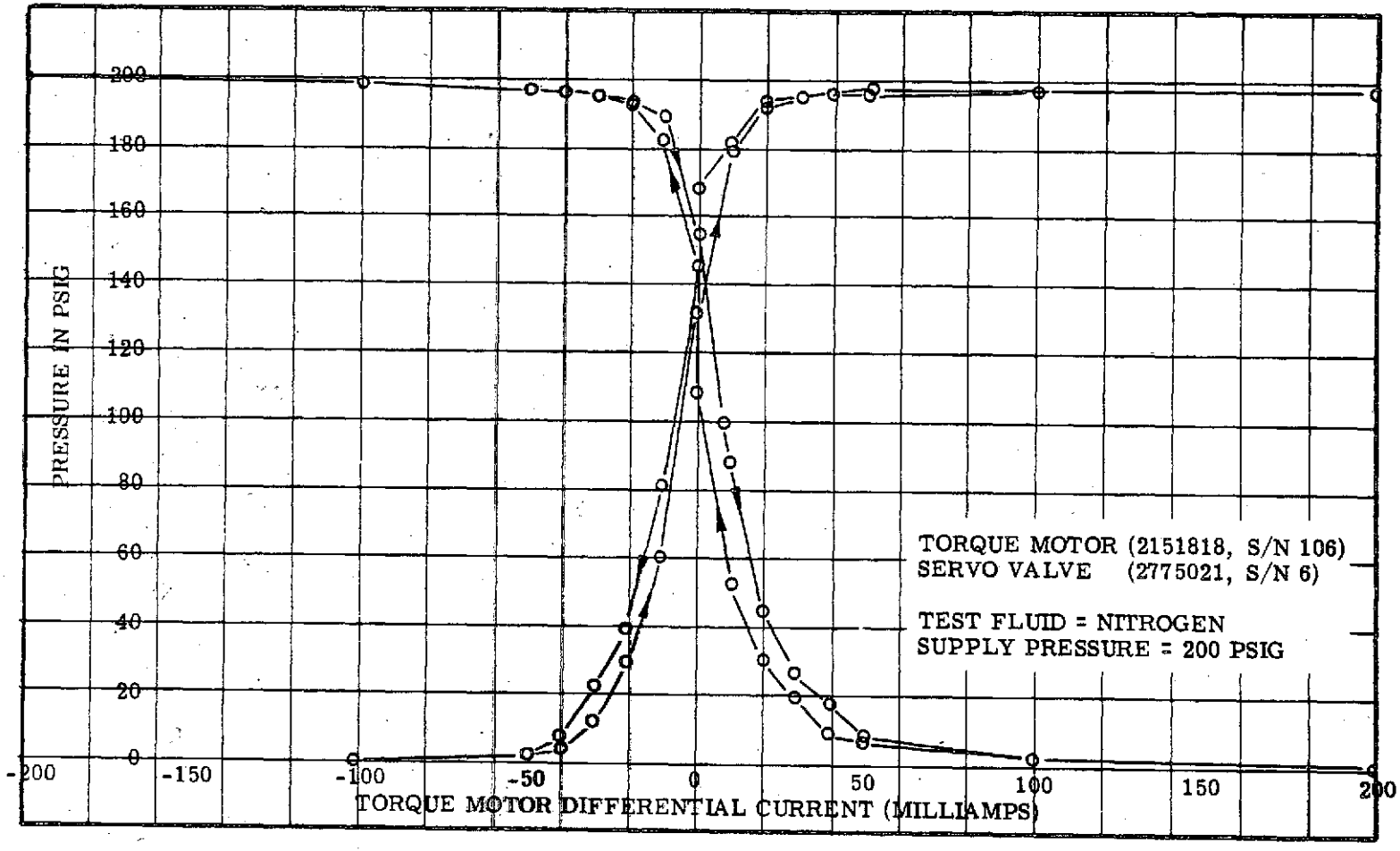

Figure 2-6. Torque Motor-Servo Valve Dead Ended Pressure Sensitivity

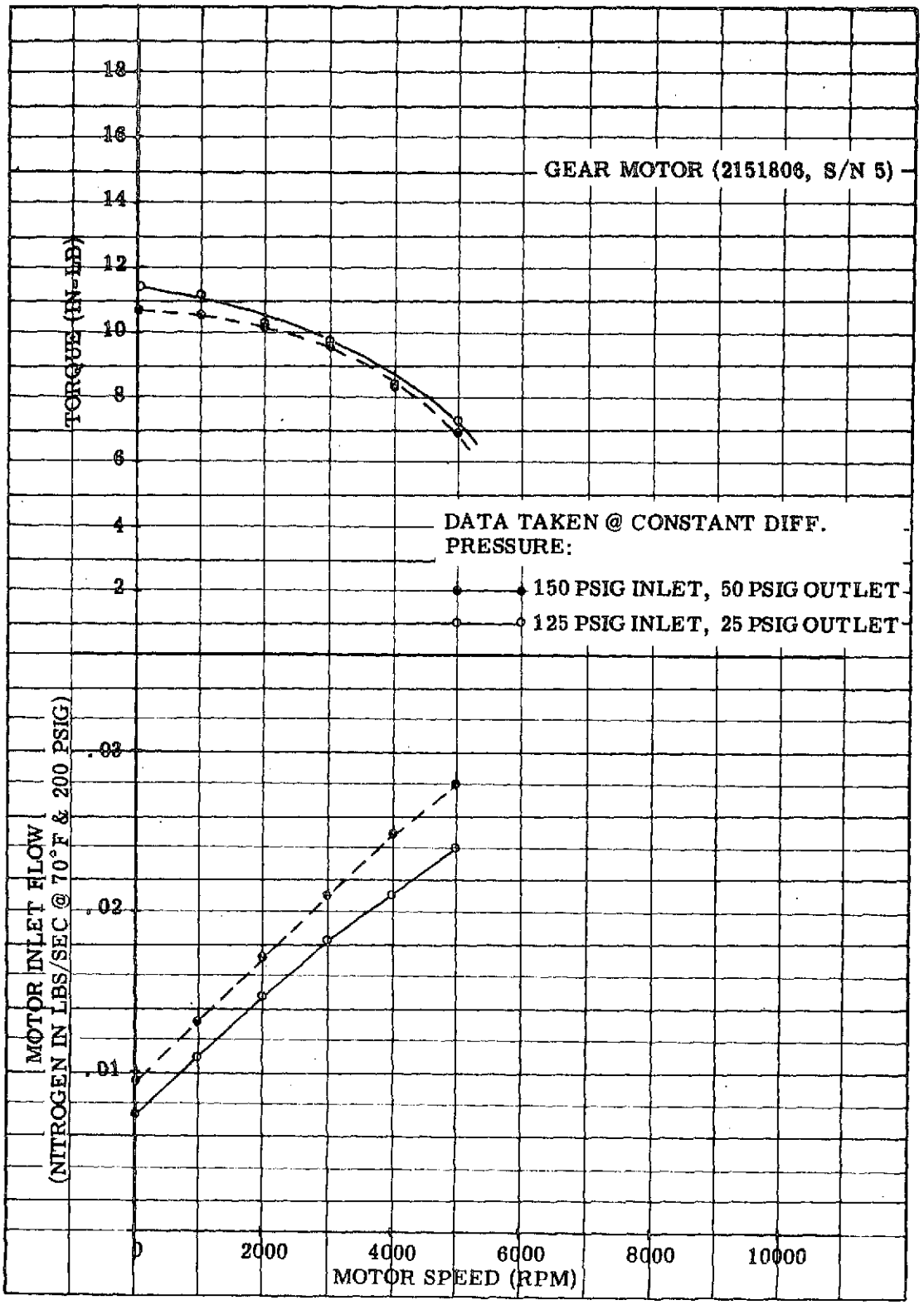

Figure 2-7. Gear Motor Torque-Speed-Flow Characteristics

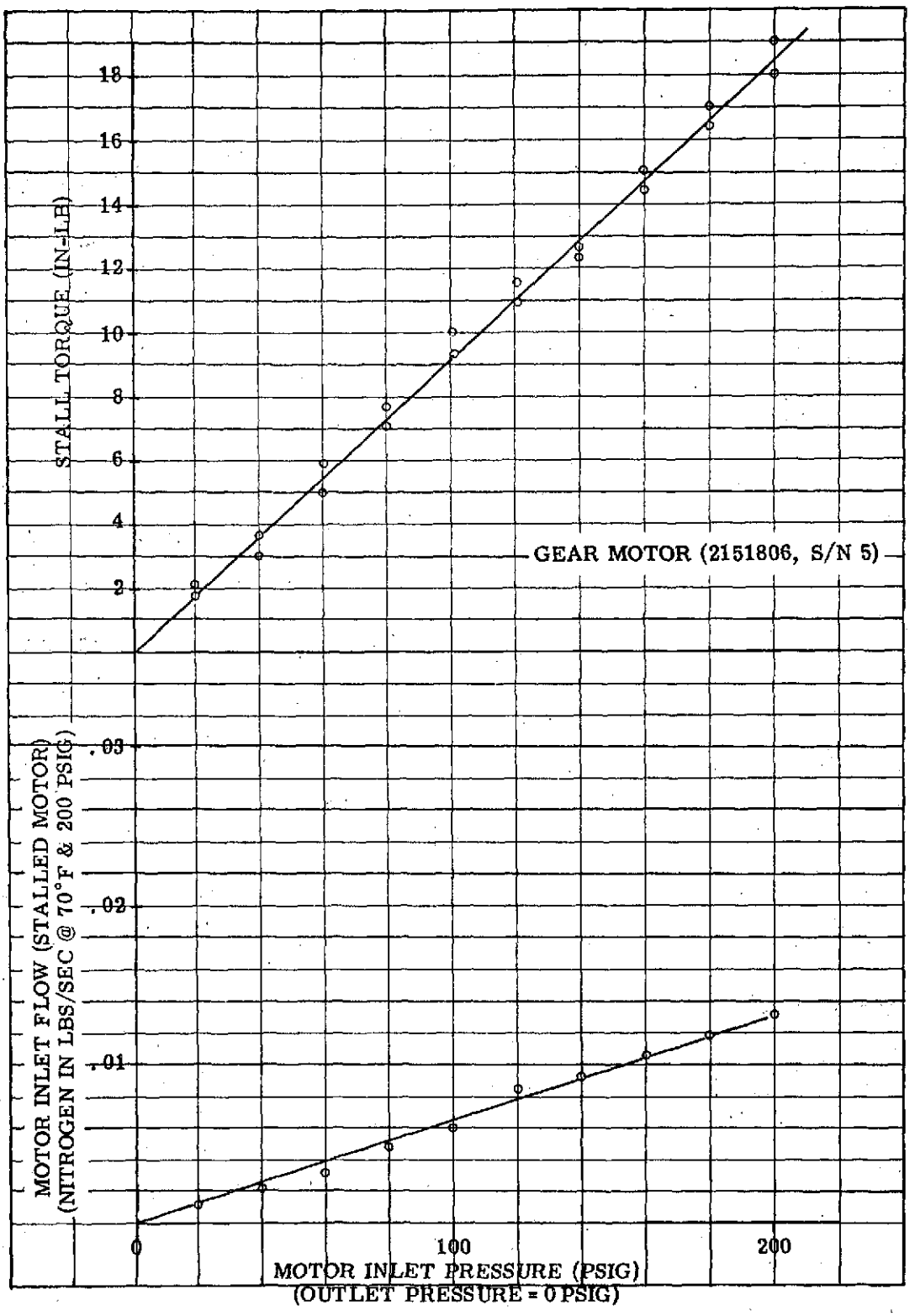

Figure 2-8. Gear Motor Stall Torque-Flow-Pressure Characteristics

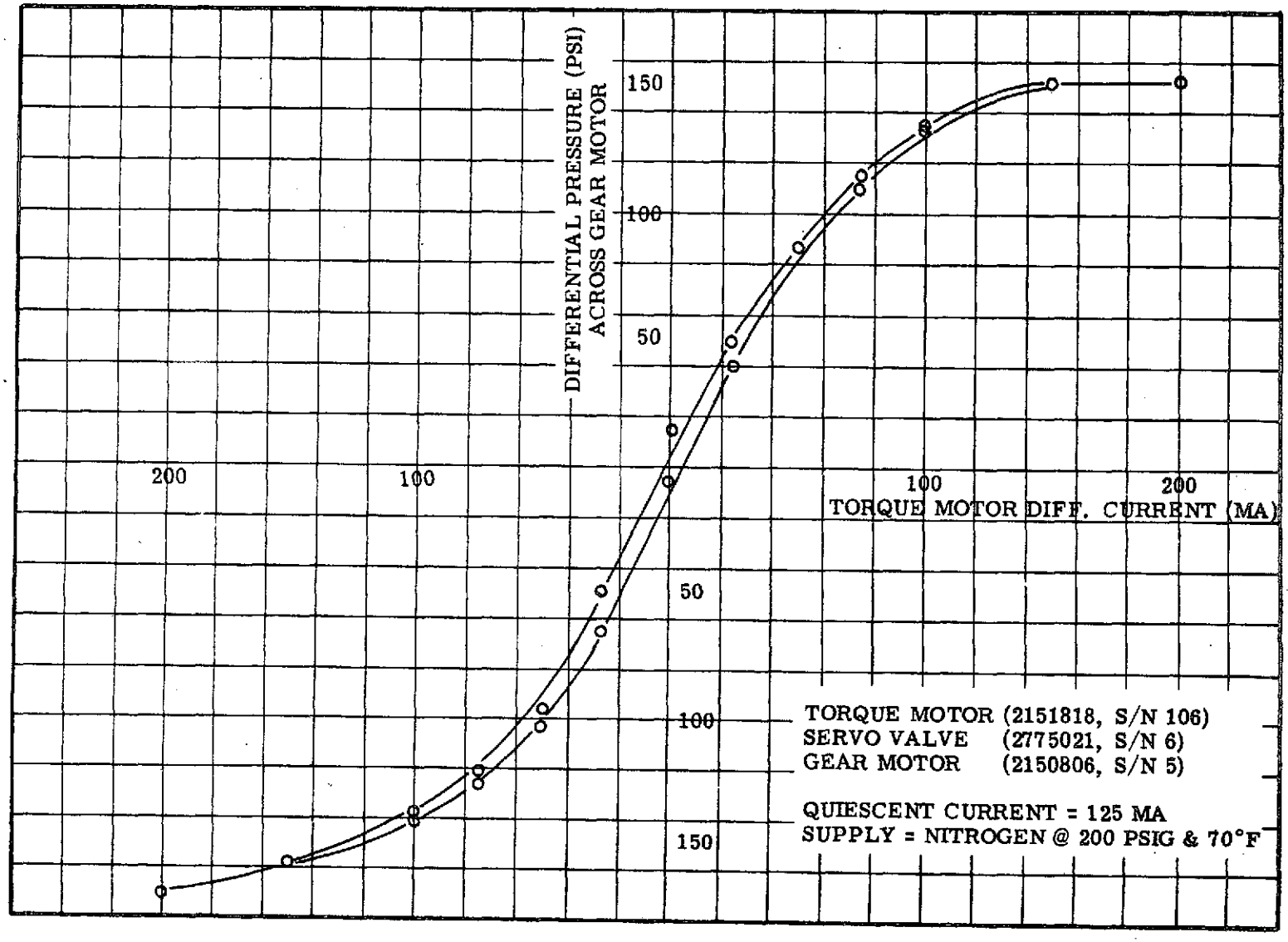

Figure 2-9. Torque Motor-Servo Valve-Gear Motor Pressure Sensitivity

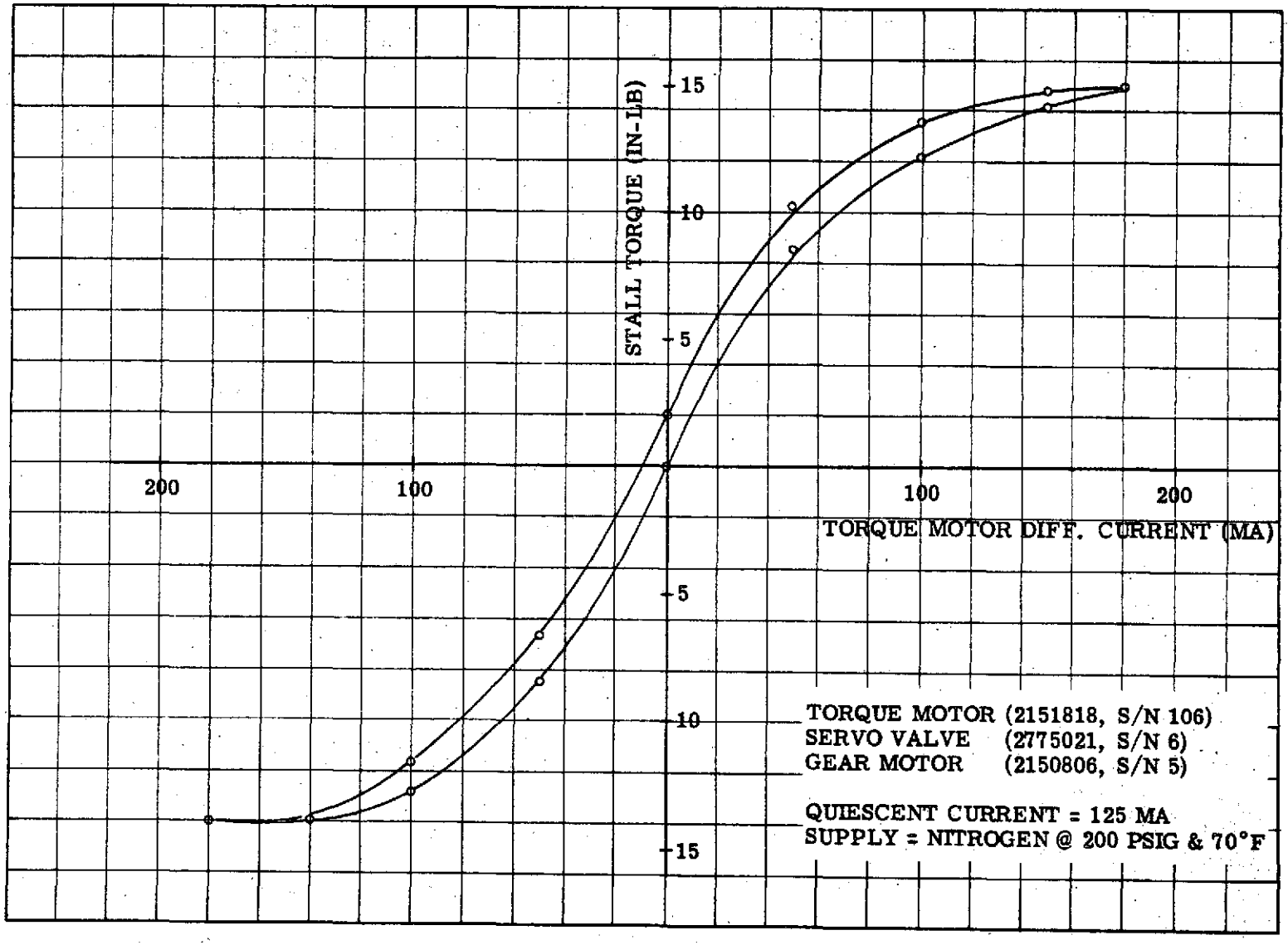

Figure 2-10. Torque Motor-Servo Valve-Gear Motor Stall Torque Characteristics

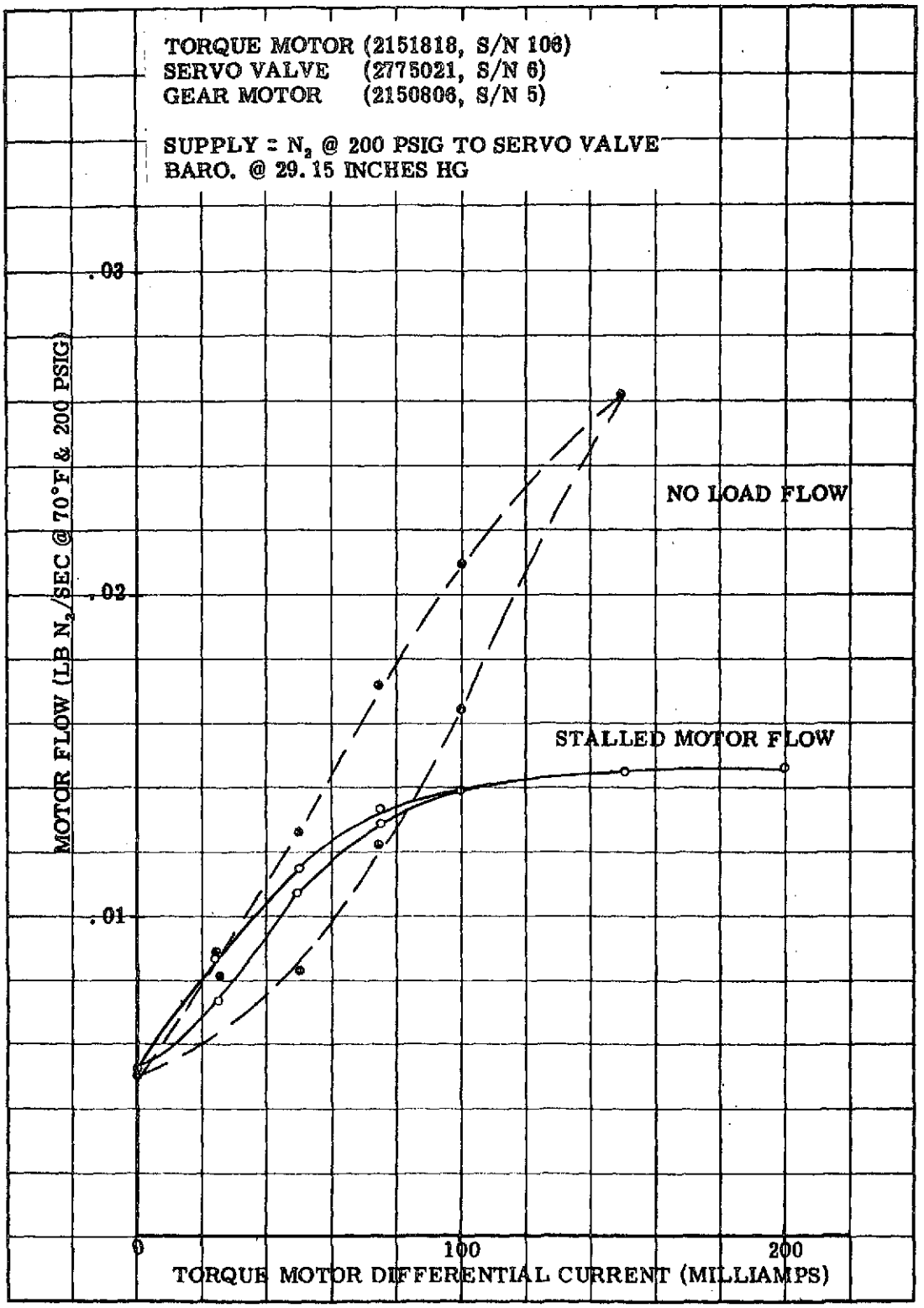

Figure 2-11. Torque Motor-Servo Valve-Gear Motor Flow Characteristics

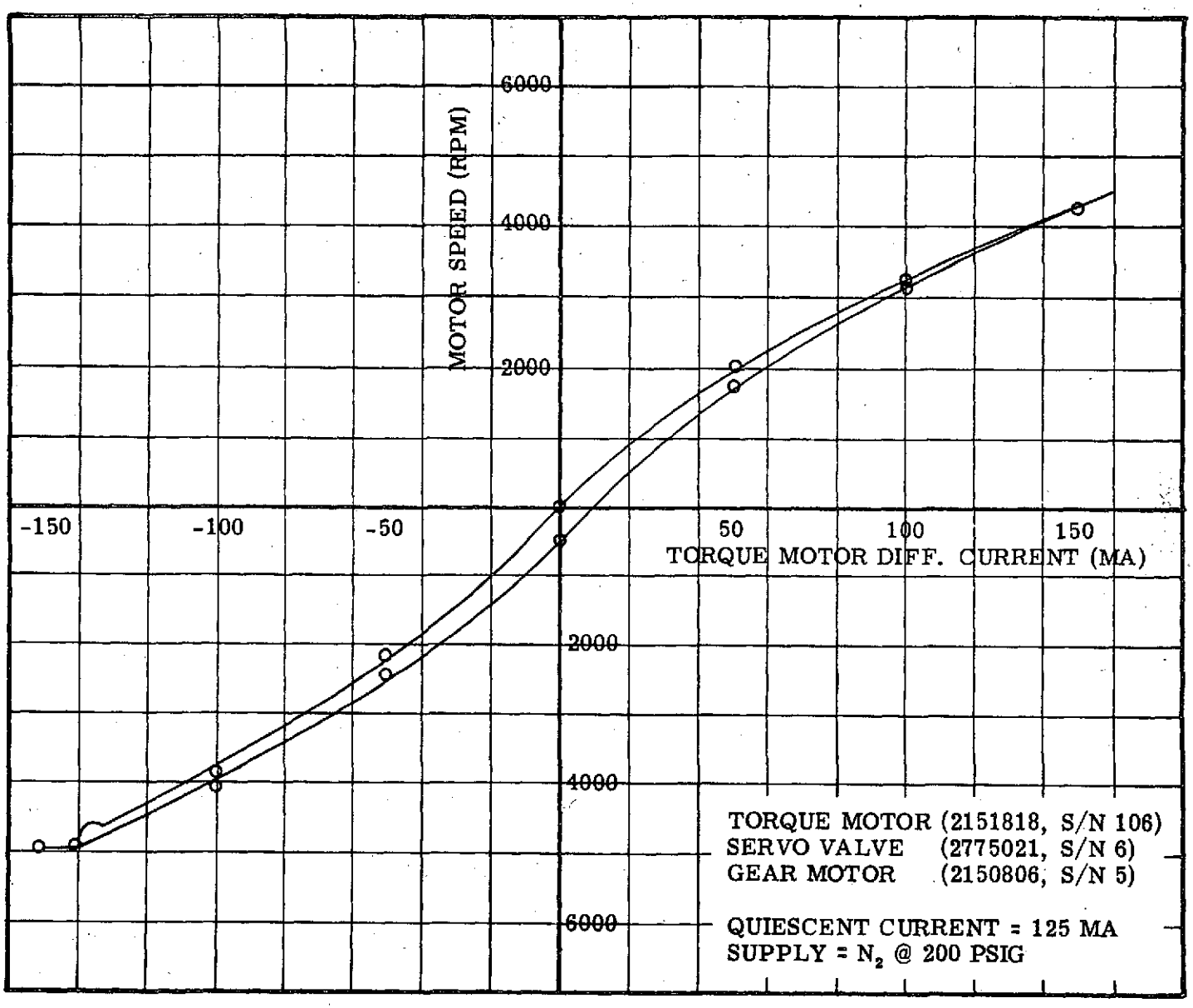

Figure 2-12. Torque Motor-Servo Valve-Gear Motor No-Load Speed Characteristics

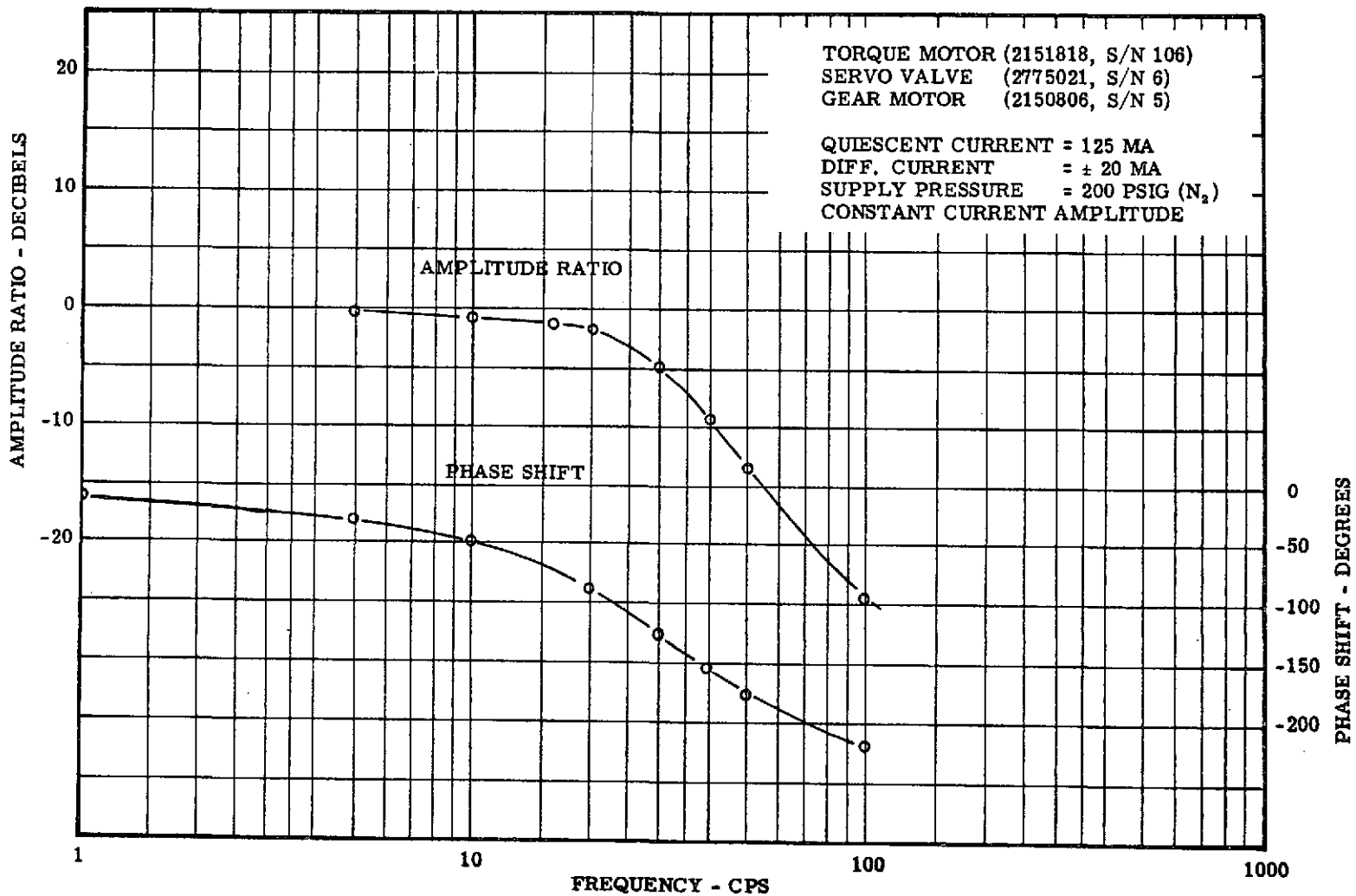

Figure 2-13. Torque Motor-Servo Valve-Gear Motor Frequency Response

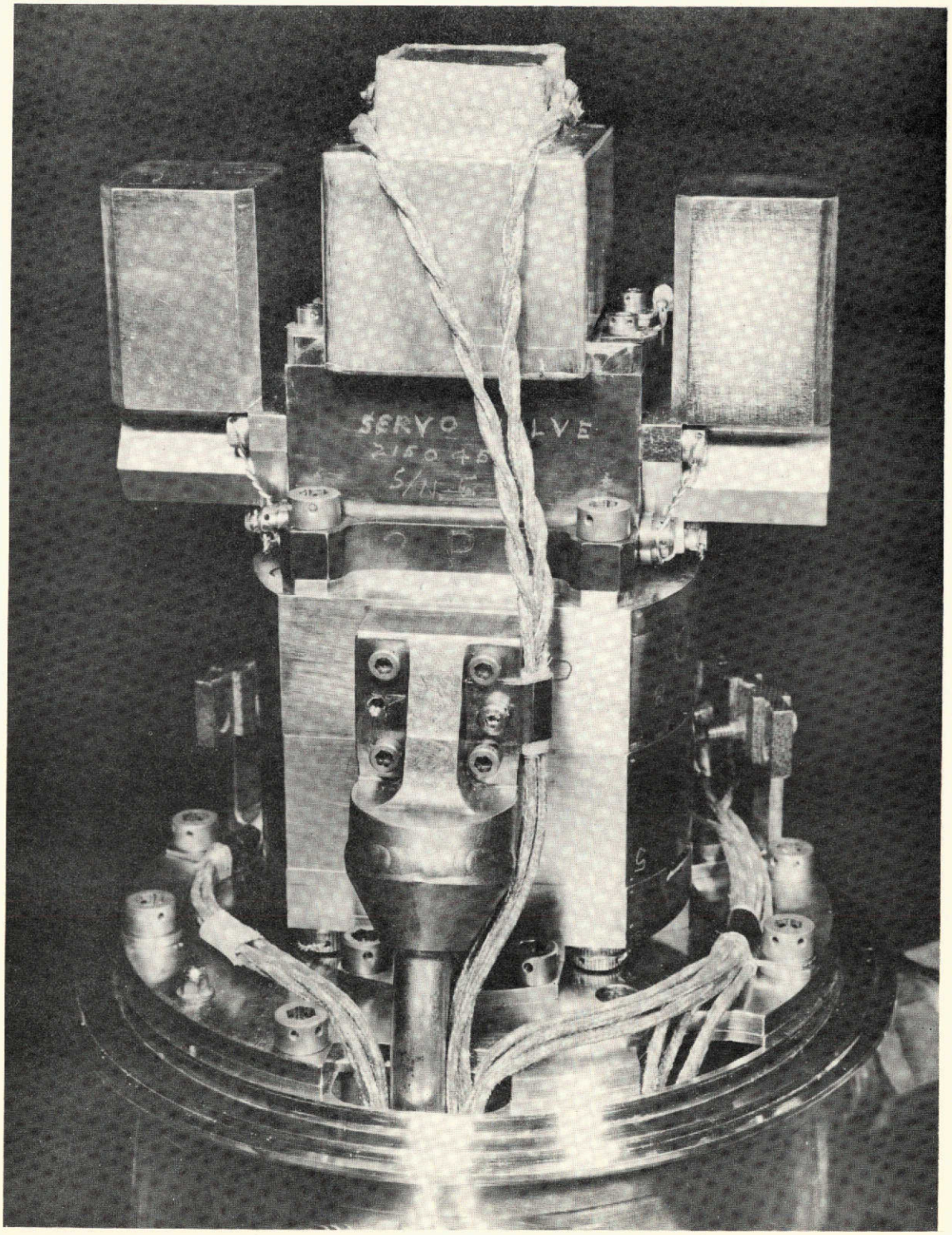

Figure 2-14. Torque Motor-Servo Valve-Gear Motor Mounted on Actuator

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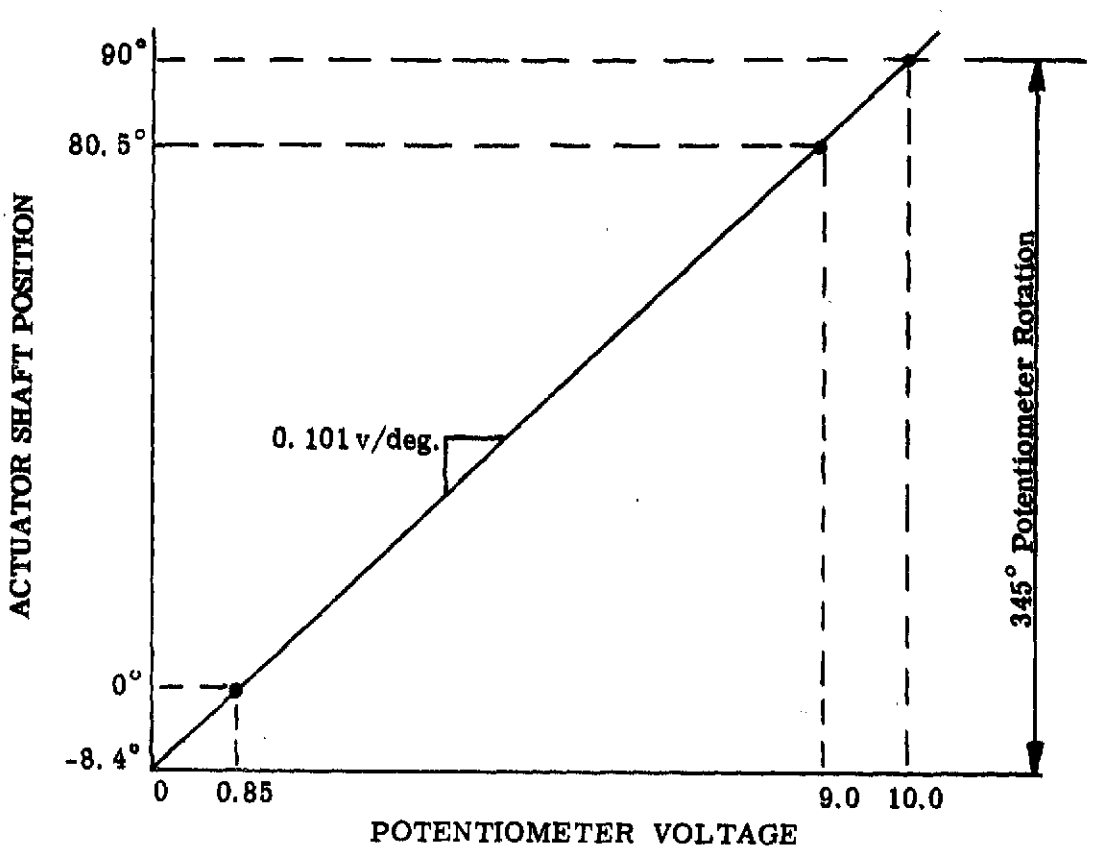

Figure 2-15. Indicating Potentiometer Voltage Relationship

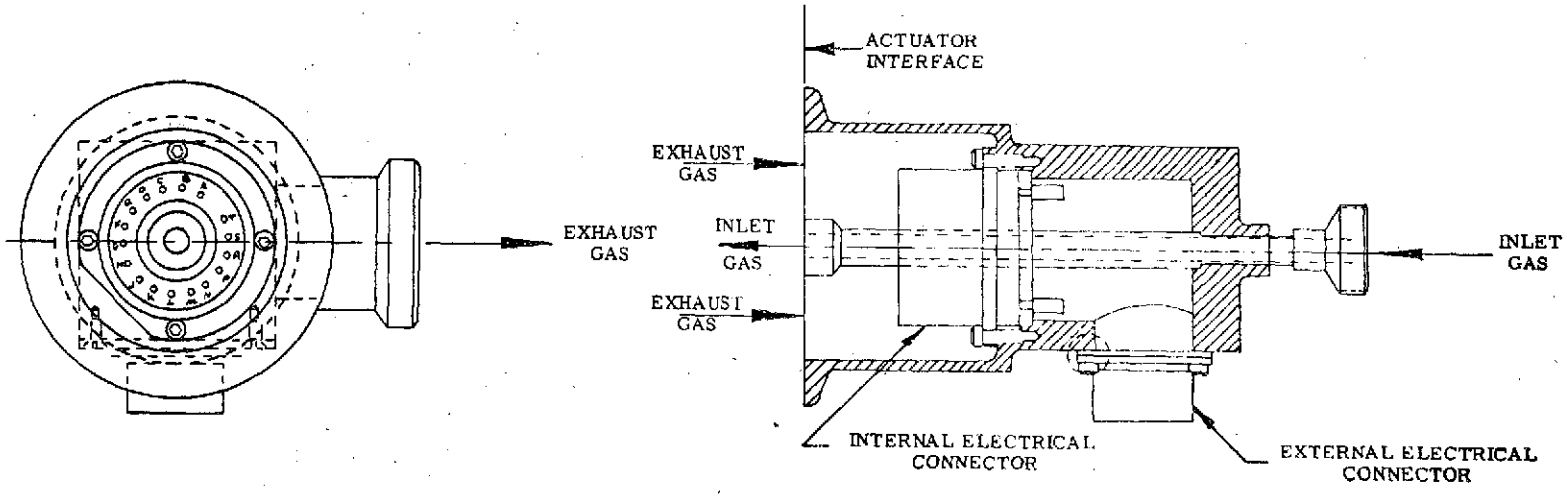

Figure 2-16. Redesigned Inlet And Outlet Connector Assembly

SECTION 3

ACTUATOR TEST RESULTS

3.1 SYSTEM TEST PROCEDURES

All test procedures and test setups used in the actuator tests are identical to those described in Section 3 of Report BPAD-863-4-14917 covering the procedure used with the Model NT-B3 Turbine Power Control Valve Actuators. Pneumatic system schematics for room temperature tests and for low temperature tests, and an electrical instrumentation schematic are included in Report BPAD-863-4-14917. Figure 3-1 shows the actuator mounted on the test fixture.

3.2 PERFORMANCE TESTS AT ROOM TEMPERATURE

Table 3-1 summarizes the room temperature tests and the results of these tests conducted under various loading conditions. The test conditions are shown in Table 3-2. Reproductions of the actual Sanborn Recorder traces taken during the testing are included in Figures 3-2 through 3-6.

3.3 PERFORMANCE TESTS AT LOW TEMPERATURES

Tests conducted at low temperature and their results are represented in Table 3-3. The test conditions referred to in this table are shown in Table 3-2. Actual Sanborn Recorder traces taken during the tests are reproduced in Figures 3-7 through 3-12.

Erratic performance of the actuator was encountered intermittently at temperatures below 180°F. The erratic performance was caused by the high noise level of the feedback signal to the magnetic amplifier, induced by the feedback potentiometer. The problem has been traced further to the material used in the slipring of the potentiometers. Efforts have been started to substitute other materials for those used in these sliprings in order to eliminate the problem.

3.4 FINAL CALIBRATION BEFORE SHIPMENT

Before shipment the actuator was recalibrated. Actual Sanborn Recorder traces of these tests are reproduced in Figures 3-13 and 3-14. Test results are shown in Table 3-4. Test conditions are shown in Table 3-2.

3.5 TOTAL ACCUMULATED TEST TIME

The total accumulated test time on the actuator assembly was 31.0 hours.

Time accumulated on the individual components before they were combined into the actuator assembly was as follows:

Torque Motor, P/N 2151818, S/N 106	21.4 hours
Servo Valve, P/N 2775021, S/N 6	12.4 hours
Gear Motor, P/N 2150806, S/N 5	17.9 hours
Transmission, P/N 2775005, S/N 1	0.5 hours

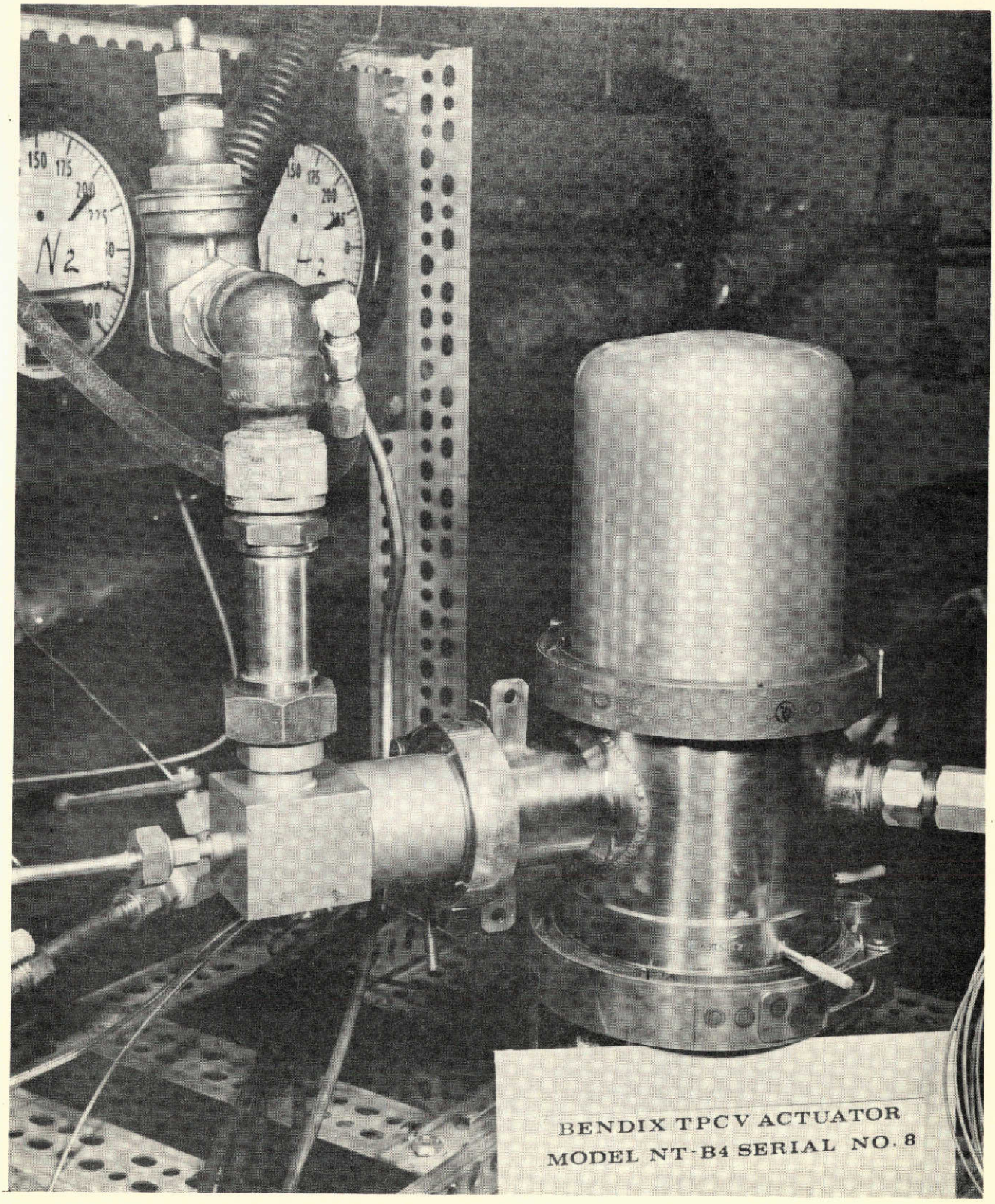

Figure 3-1. NT-B4 Turbine Power Control Valve Actuator On Test Fixture

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Test	Load Condition	Forcing Function	Temp. of Inlet Gas Degrees F	Test Results	Figure Number
Dynamic Resolution	A	± 5° ramp at 0.05 CPS around 30° pos.	38	Resolution: 0.22°	3-2
Transient Response	A	45° step at 0.3 CPS around 43° position	38	Overshoot: 17.8% Settling Time: 0.22 sec. 62% Rise Time: 0.096 sec.	3-2
Slew Velocity	A	45° step around 43° position	38	Velocity 417°/sec., decreasing angle 434°/sec., increasing angle *	3-2
Frequency Response	A	± 2° sine wave around 30° pos. 0.5 through 24 CPS	38	-90° phase shift at approx. 11 CPS -180° phase shift at approx. 19 CPS	3-3
Dynamic Resolution	B	± 5° ramp at 0.05 CPS around 30° position	38	Resolution: 0.14°	3-4
Transient Response	B	45° step at 0.3 CPS around 43° position	38	Overshoot: 19% decr. angle 14.5% increasing angle Settling Time: 0.19 sec. incr. and decreasing angle 62% Rise Time: 0.10 sec. incr. 0.097 sec. decr. angle	3-4
Slew Velocity	B	45° step around 43° position	38	Velocity 500°/sec., decreasing angle 435°/sec., increasing angle *	3-4
Frequency Response	B	± 2° sine wave around 30° pos. 0.5 through 24 CPS	38	-90° phase shift at approx. 11 CPS -180° phase shift at approx. 19 CPS	3-5
Dynamic Resolution	C	± 5° ramp at 0.05 CPS around 30° position	42	Resolution: 0.13°	3-6
Transient Response	C	45° step at 0.3 CPS around 43° position	42	Overshoot: 22% decr. angle 17% increasing angle Settling Time: 0.196 sec. for both incr. & decr. angles 62% Rise Time: 0.10 sec. incr. 0.095 sec. decr. angle	3-6
Slew Velocity	C	45° step around 43° position	42	Velocity 565°/sec decr. angle 445°/sec incr. angle *	3-6

*Required velocity 360°/sec. min.

Table 3-1. Summary Of Tests And Test Results - Room Temperature

Test Condition	Friction Load In. Lbs.	Torsional Spring Load In. Lbs/Degree	Shaft Seal Pressure PSIG	Actuator Exhaust Back Pressure PSIG
A	0	0	0	35
B	0	1.5	0	35
C	0	1.5	0	0
D	0	1.5	650	35
E	0	1.5	650	0
Supply Gas: Hydrogen at 200 PSIG				

Table 3-2. Test Conditions

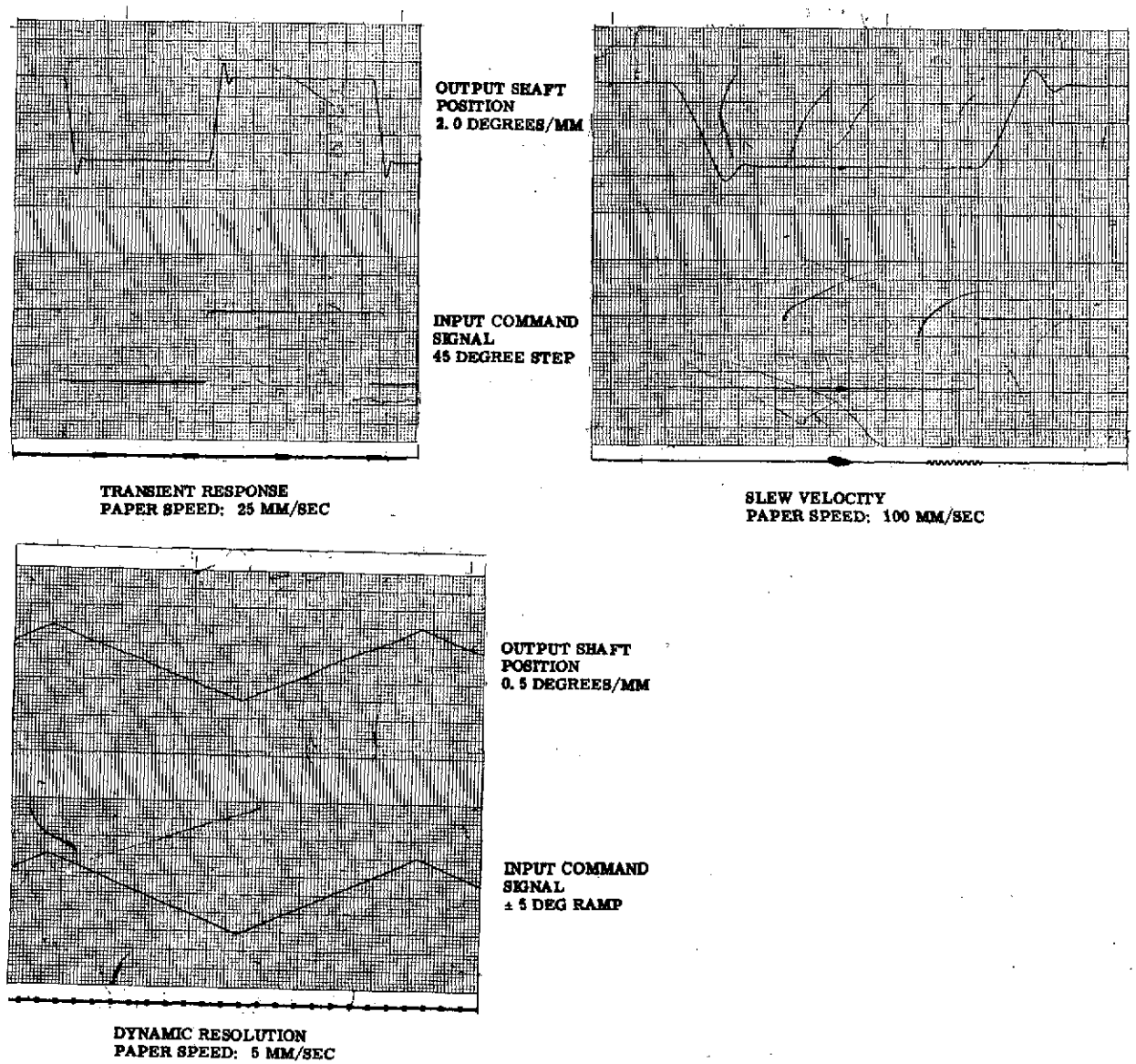


Figure 3-2. Dynamic Resolution, Transient Response and Slew Velocity for Test Conditions (See Table 3-1)

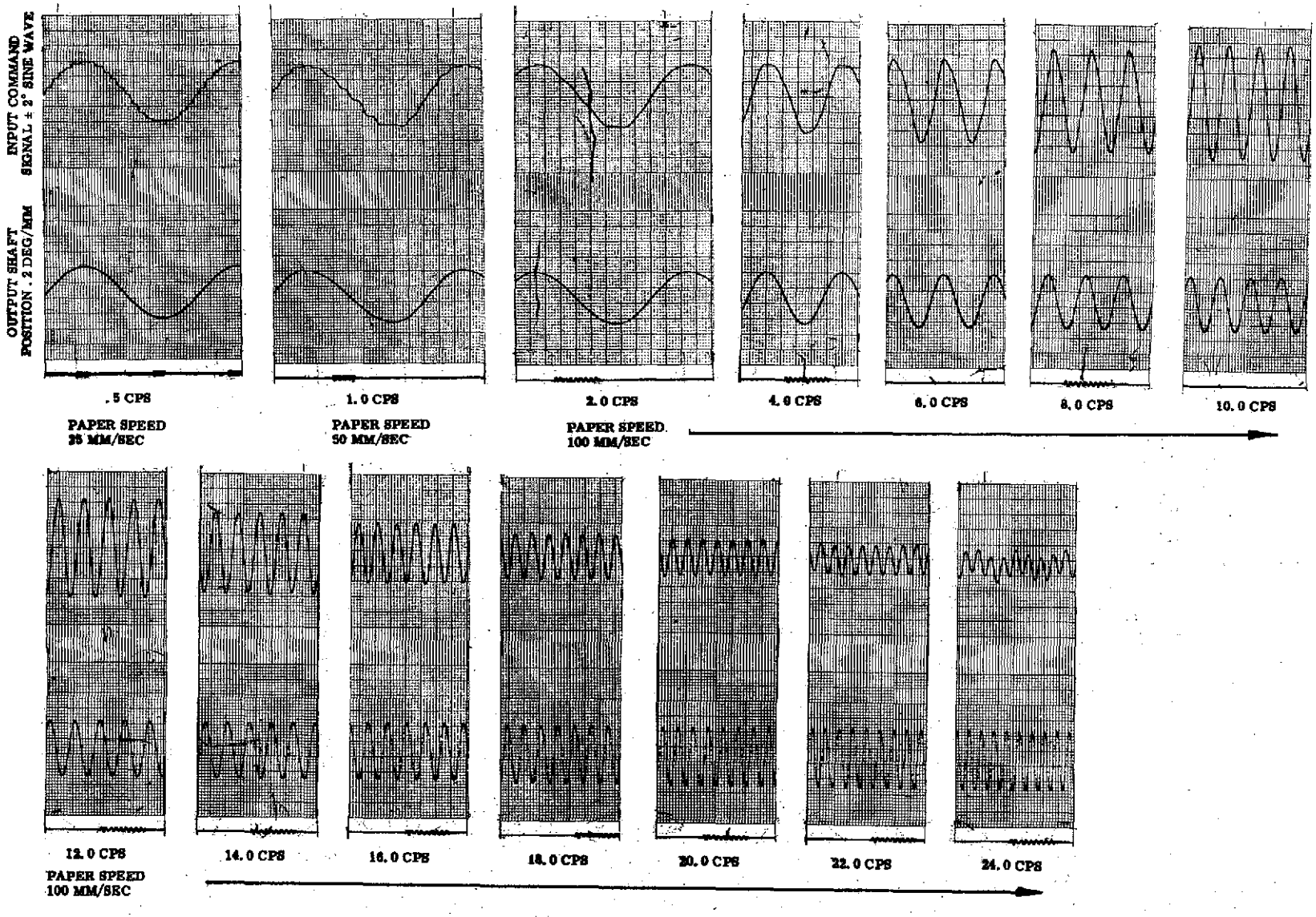


Figure 3-3. Frequency Response for Test Conditions

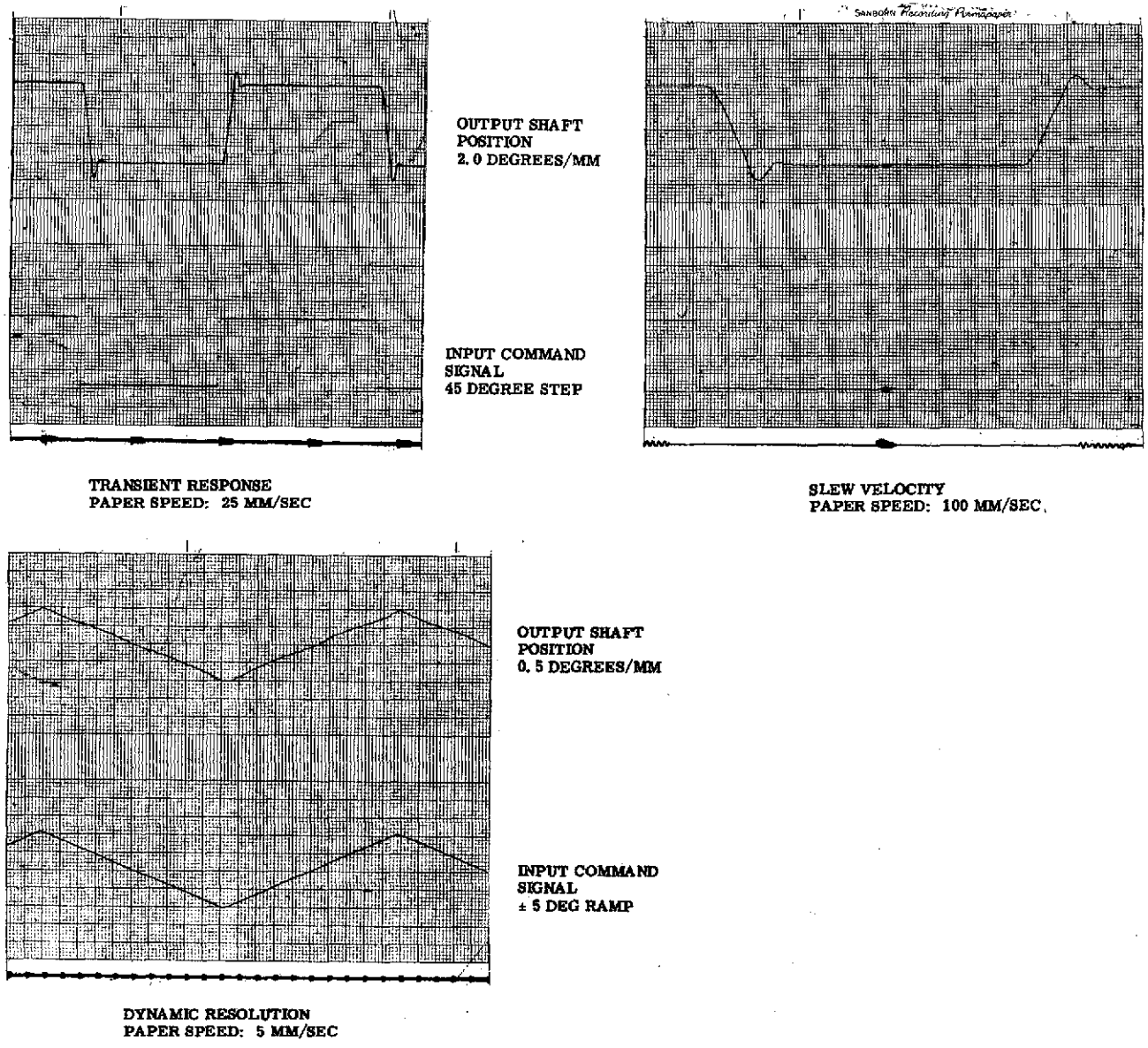


Figure 3-4. Dynamic Resolution, Transient Response, and Slew Velocity for Test Conditions (See Table 3-1)

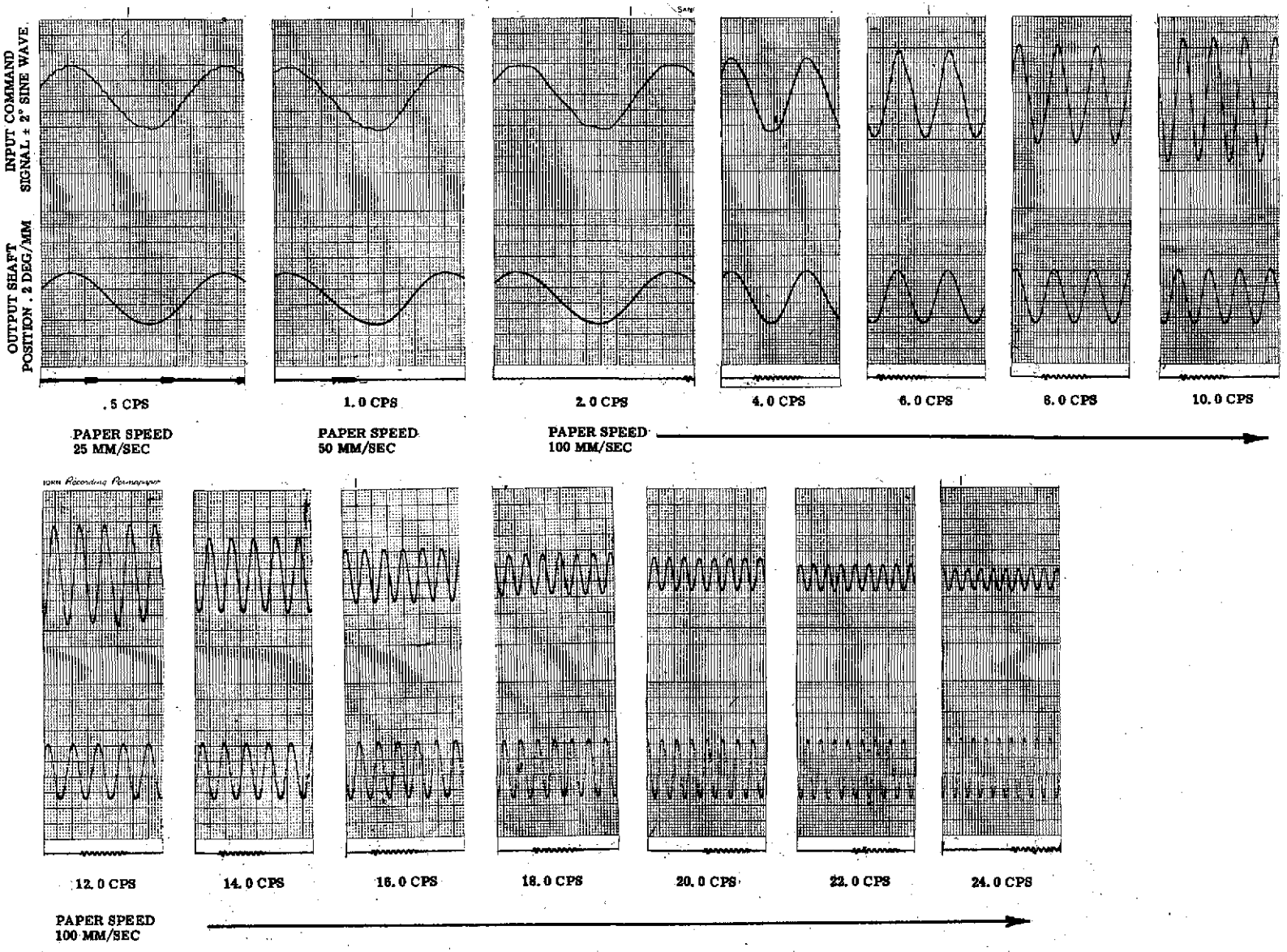
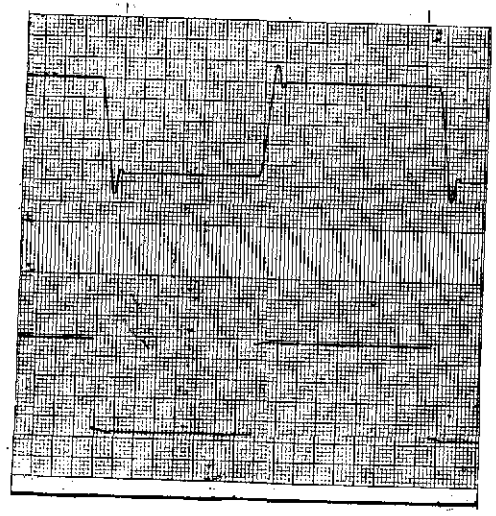


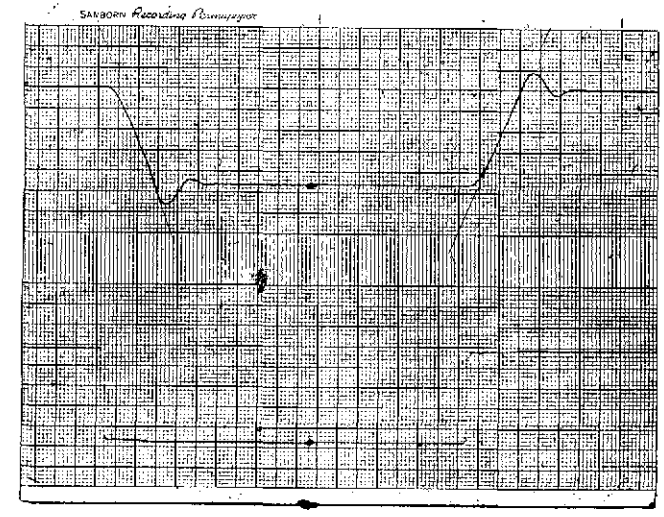
Figure 3-5. Frequency Response for Test Conditions (See Table 3-1)



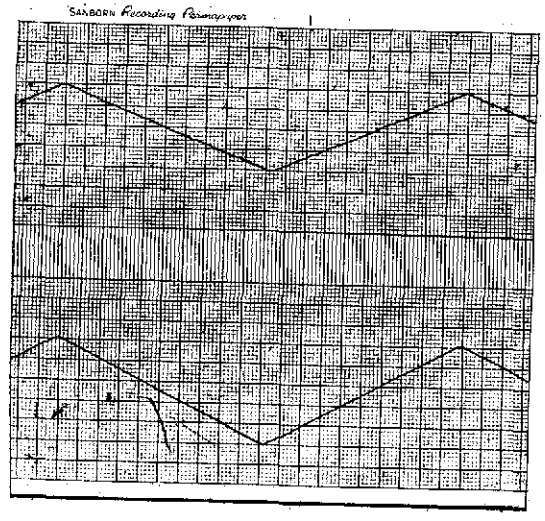
OUTPUT SHAFT
POSITION
2.0 DEGREES/MM

INPUT COMMAND
SIGNAL
45 DEGREE STEP

TRANSIENT RESPONSE
PAPER SPEED: 25 MM/SEC



SLEW VELOCITY
PAPER SPEED: 100 MM/SEC



OUTPUT SHAFT
POSITION
0.5 DEGREES/MM

INPUT COMMAND
SIGNAL
± 5 DEG RAMP

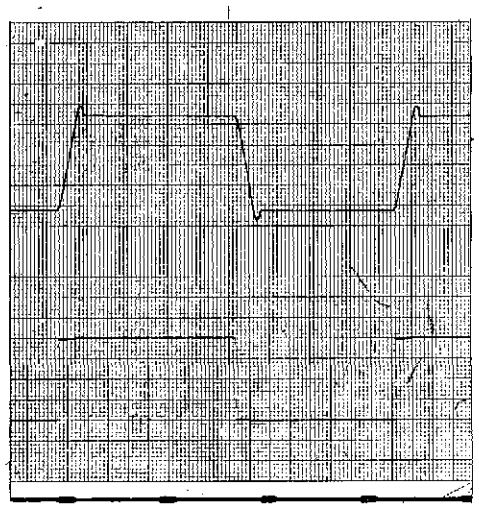
DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC

Figure 3-6. Dynamic Resolution, Transient Response, and Slew Velocity for Test Conditions (See Table 3-1)

Test	Load Condition	Forcing Function	Temp. of Inlet Gas In. Degr. F	Test Results	Figure Number
Dynamic Resolution	C	± 5° ramp at 0.05 CPS around 30° pos.	-275	Resolution: 0.24°	3-7
Transient Response	C	45° step at 0.3 CPS around 43° position	-278	Overshoot: 10.4% decreasing angle 10.6% increasing angle Settling Time: 0.25 sec. increasing 0.23 sec. decreasing angle 62% Rise Time: 0.121 both increasing and decreasing angles	3-7
Slew Velocity	C	45° step around 43° position	-278	Velocity 260°/sec. increasing angle 316°/sec. decreasing angle *	3-7
Frequency Response	C	± 2° sine wave around 30° pos. 0.5 through 24 CPS	-278	-90° phase shift at approx. 9 CPS. -180° phase shift at approx. 19 CPS.	3-8
Dynamic Resolution	D	± 5° ramp at 0.05 CPS around 60° position	-265	Resolution: 0.22°	3-9
Transient Response	D	45° step at 0.3 CPS around 60° position	-257	Overshoot: 14% increasing angle, 13% decreasing angle Settling Time: 0.233 sec. decr. 0.292 sec. increasing angle 62% Rise Time: 0.116 sec. decr. 0.292 sec. increasing angle	3-9
Slew Velocity	D	45° step around 60° position	-249	Velocity 360°/sec. decreasing angle 250°/sec. increasing angle *	3-9
Frequency Response	D	± 2° sine wave around 60° pos. 0.5 through 24 CPS	-278° to -265	-90° phase shift at approx. 10 CPS. -180° phase shift at approx. 18 CPS	3-10
Dynamic Resolution	E	± 5° ramp at 0.05 CPS around 30° position	-278	Resolution: 0.18°	3-11
Transient Response	E	45° step at 0.3 CPS around 43° position	-278	Overshoot: 14.9% increasing 9.8% decreasing Settling Time: 0.28 sec. increasing 0.25 sec. decreasing angle 62% Rise Time: 0.13 sec. decr. 0.14 sec. increasing angle	3-11
Slew Velocity	E	45° step around 43° position	-278	Velocity 283°/sec. decreasing angle 244°/sec. increasing angle *	3-11
Frequency Response	E	± 2° sine wave around 30° pos.	-278	-90° phase shift at approx. 10 CPS. -180° phase shift at approx. 19 CPS.	3-12

*Required velocity 360°/sec. min.

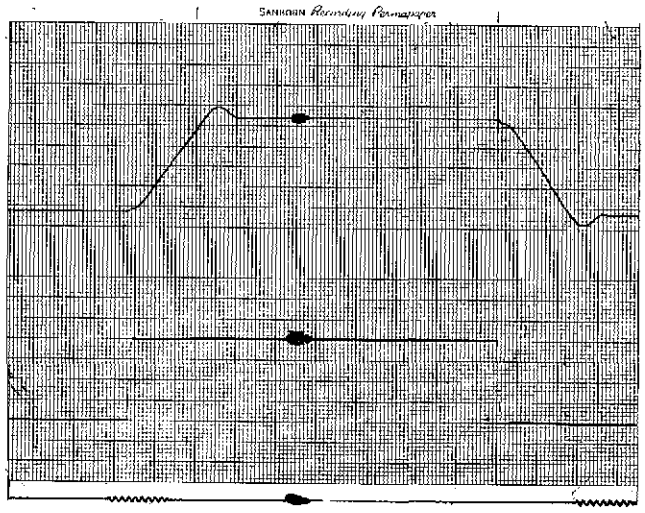
Table 3-3. Summary Of Tests And Test Results - Low Temperature



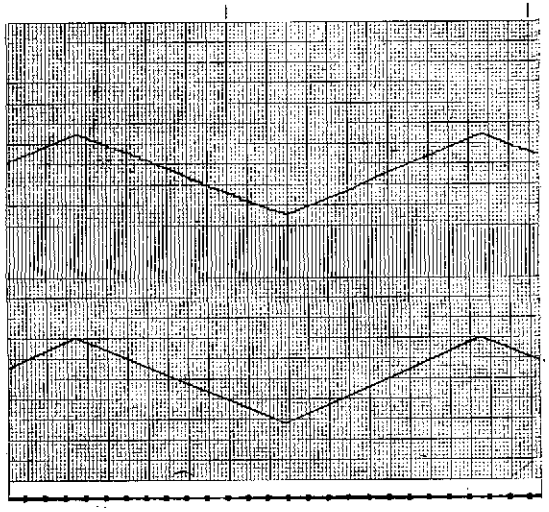
OUTPUT SHAFT
POSITION
2.0 DEGREES/MM

INPUT COMMAND
SIGNAL
45 DEGREE STEP

TRANSIENT RESPONSE
PAPER SPEED: 25 MM/SEC



SLEW VELOCITY
PAPER SPEED: 100 MM/SEC



OUTPUT SHAFT
POSITION
0.5 DEGREES/MM

INPUT COMMAND
SIGNAL
± 5 DEG RAMP

DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC

Figure 3-7. Dynamic Resolution Transient Response, and Slew Velocity for Test Conditions (See Table 3-3)

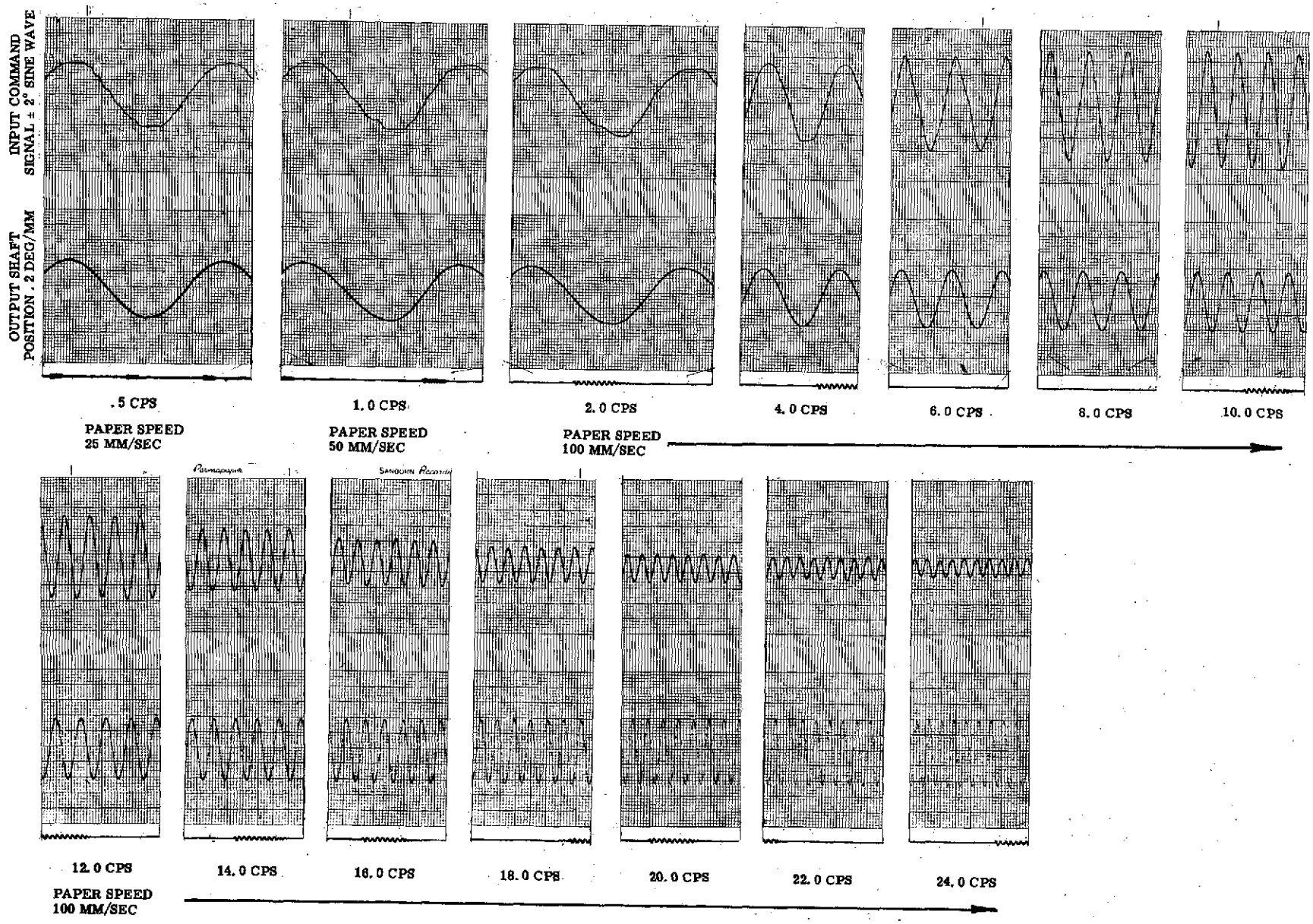


Figure 3-8. Frequency Response for Test Conditions (See Table 3-3)

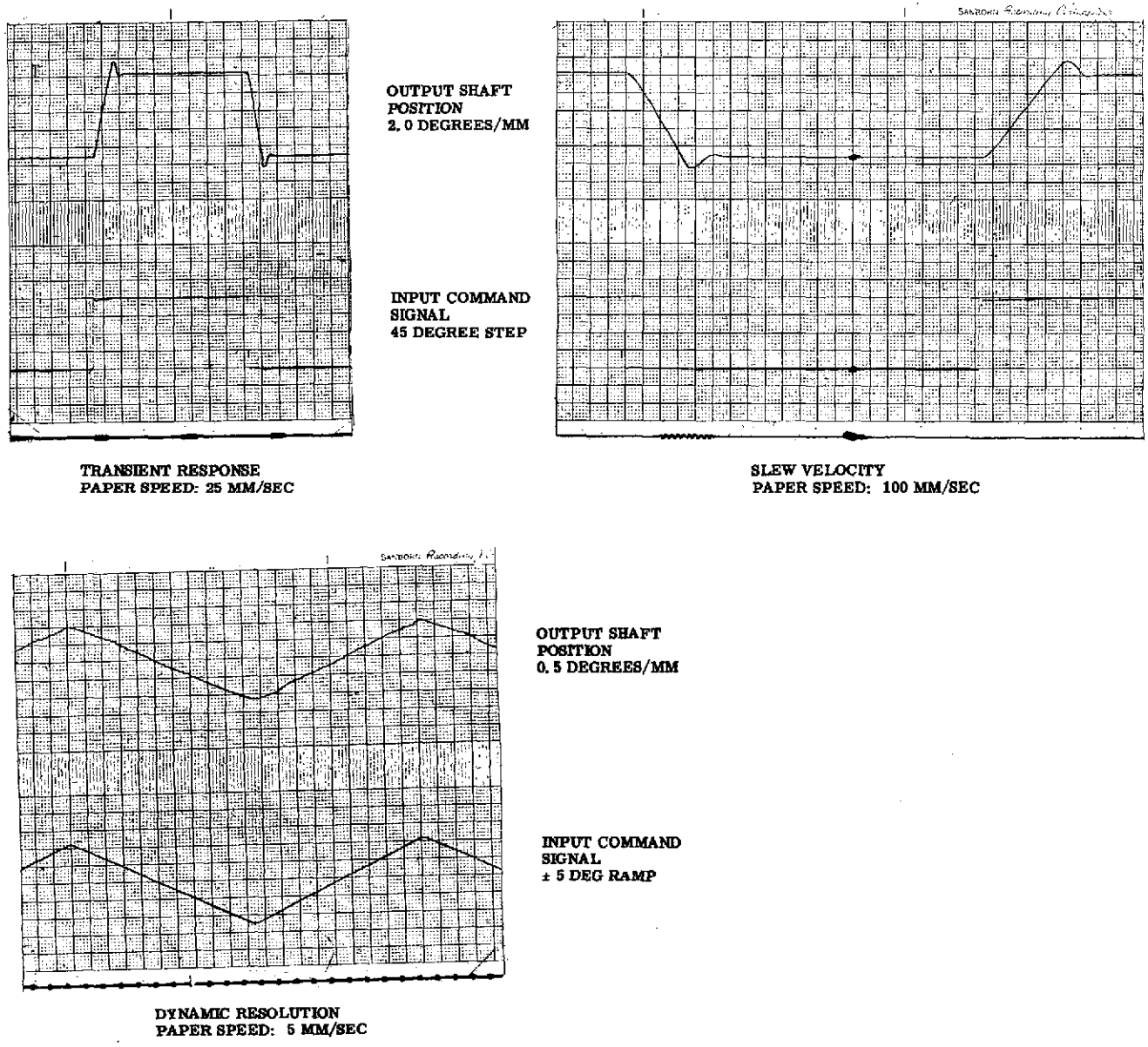


Figure 3-9. Dynamic Resolution, Transient Response, and Slew Velocity for Test Conditions (See Table 3-3)

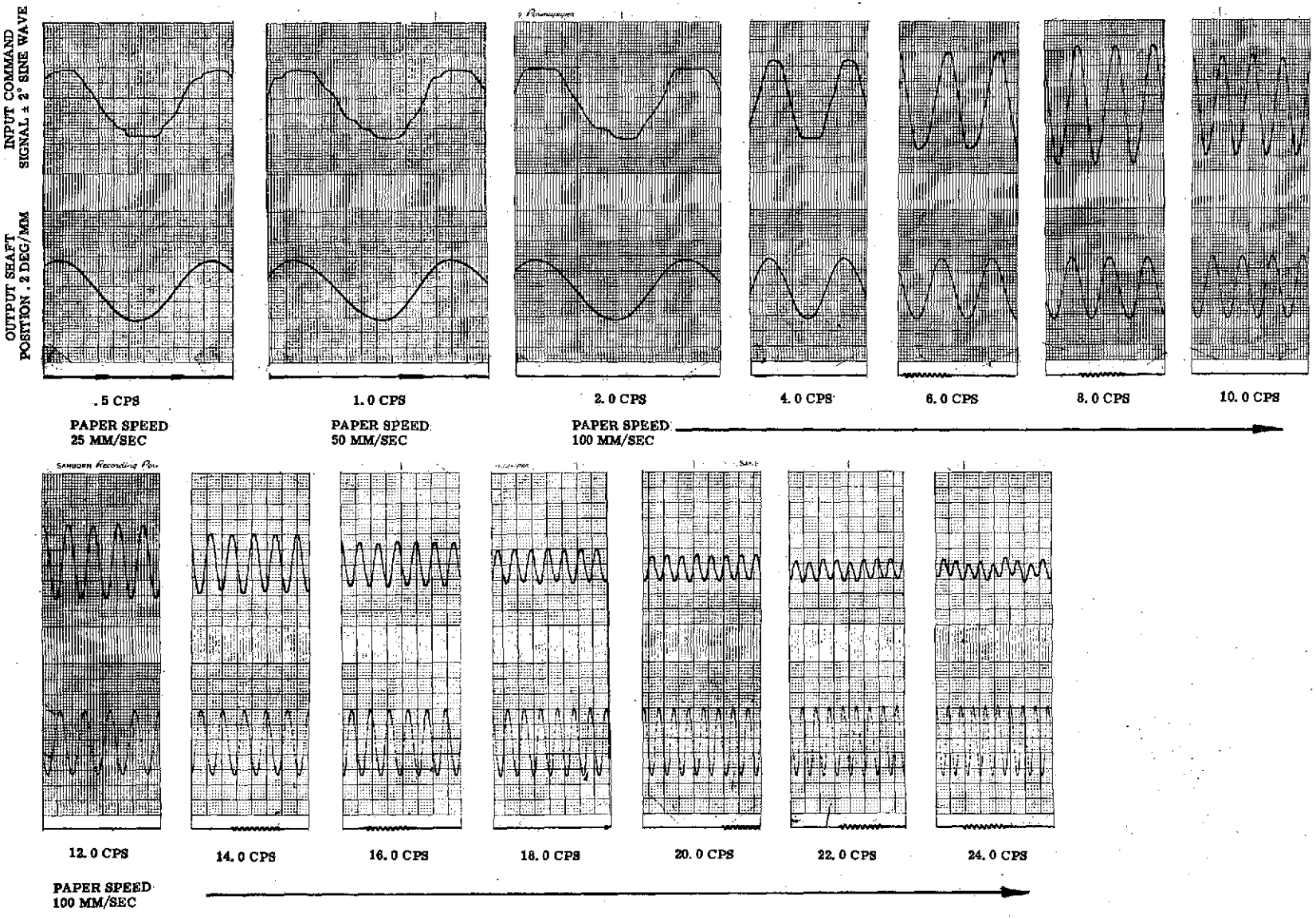


Figure 3-10. Frequency Response for Test Conditions (See Table 3-3)

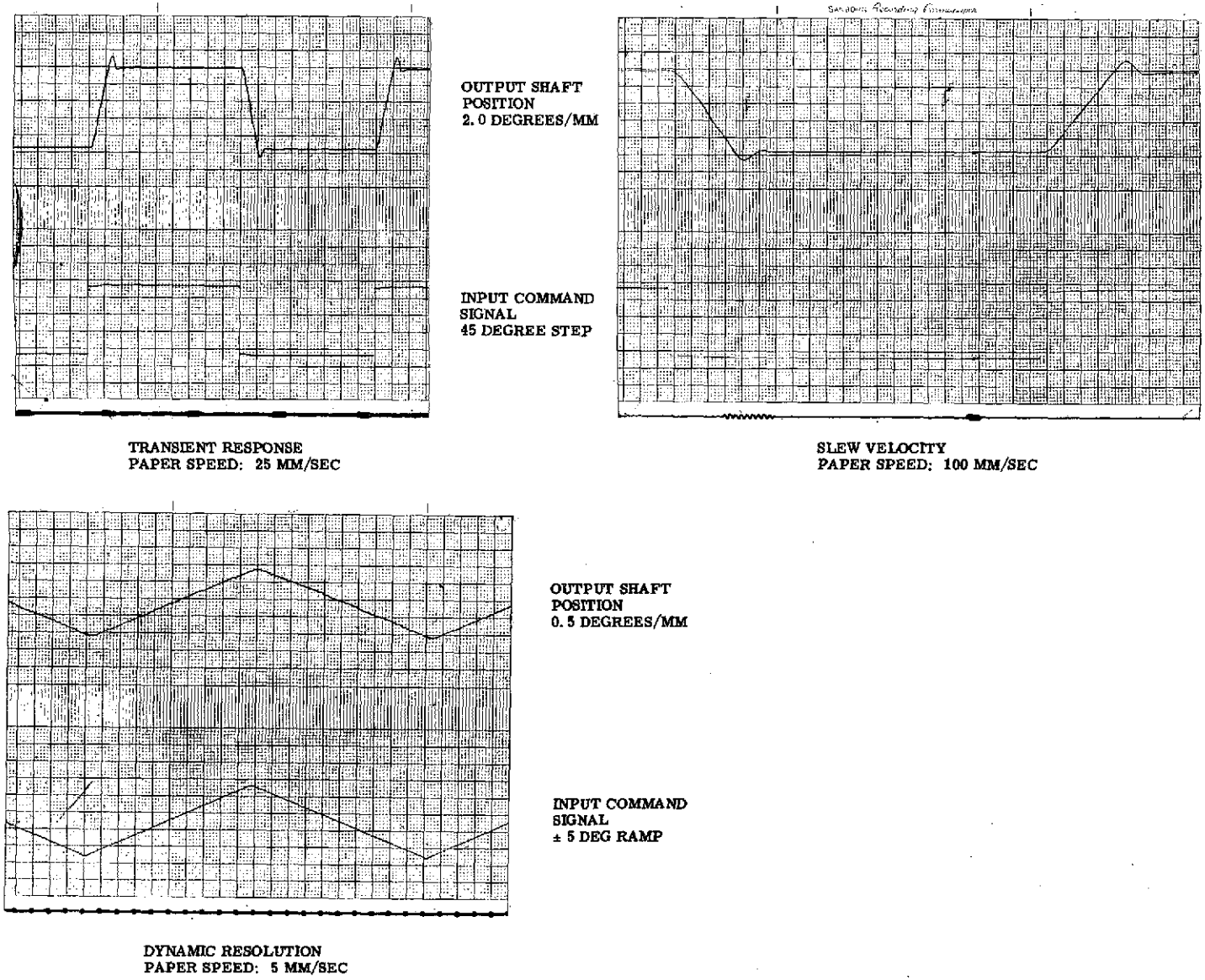


Figure 3-11. Dynamic Resolution, Transient Response, and Slew Velocity for Test Conditions (See Table 3-3)

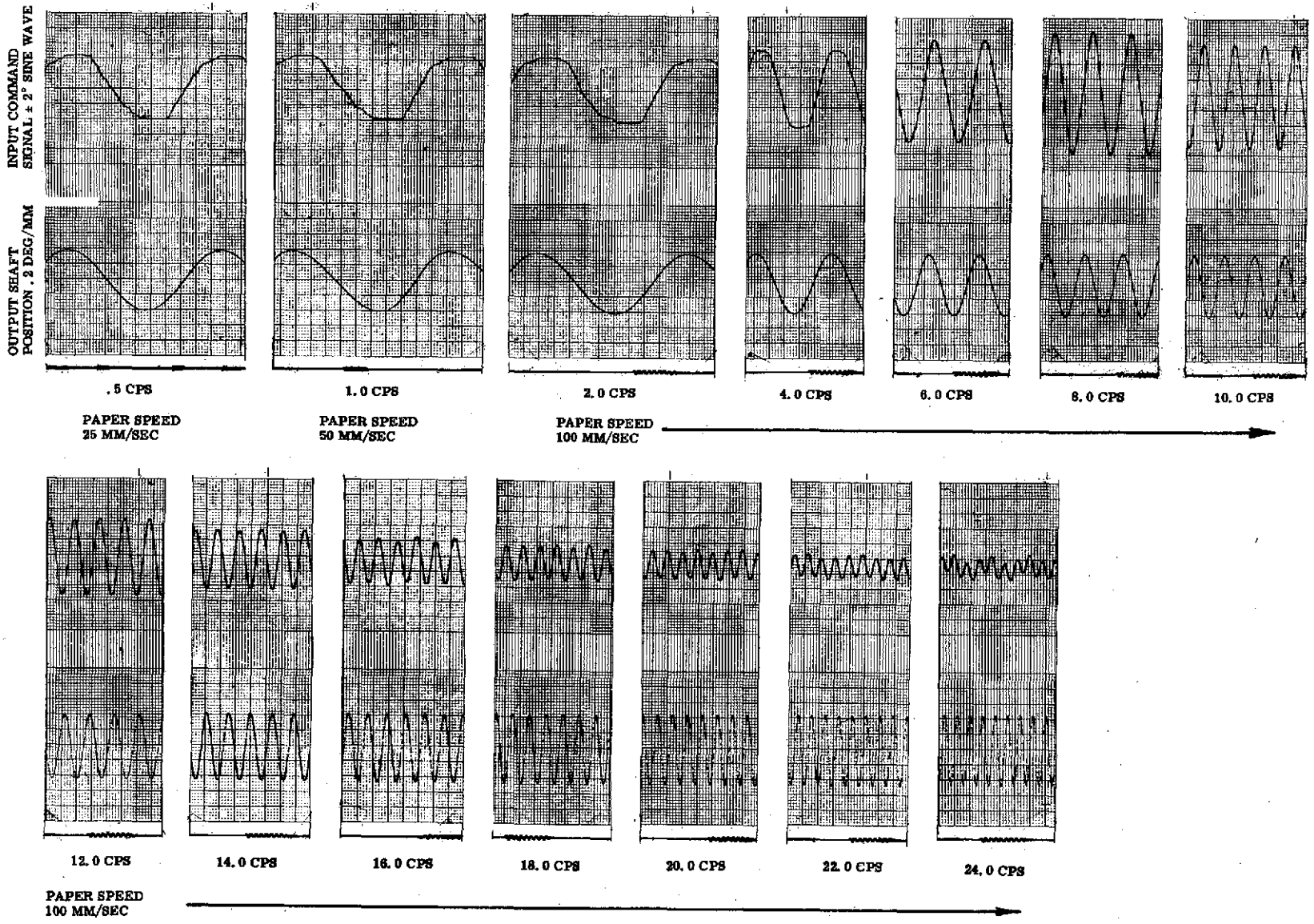


Figure 3-12. Frequency Response for Test Conditions (See Table 3-3)

Test	Load Condition	Forcing Function	Temp. of Inlet Gas Degrees F	Test Results	Figure Number
Dynamic Resolution	D	± 5° ramp at 0.05 CPS around 30° position	60	Resolution: 0.20°	3-13
Transient Response	D	45° step around 43° position at 0.3 CPS	60	Overshoot: 20.4% decreasing angle 20% increasing angle Settling Time: 0.21 sec. for both incr. & decr. angles 62% Rise Time: 0.098 sec. both incr. & decr. angles	3-13
Slew Velocity	D	45° step around 43° position	60	Velocity 483°/sec. decreasing angle 446°/sec. increasing angle *	3-13
Frequency Response	D	± 2° sine wave around 30° pos. 0.5 through 24 CPS	60	-90° phase shift at approx. 11 CPS. -180° phase shift at approx. 22 CPS.	3-14

*Required slew velocity 360°/sec. minimum

Table 3-4. Summary Of Tests And Test Results - Final Calibration

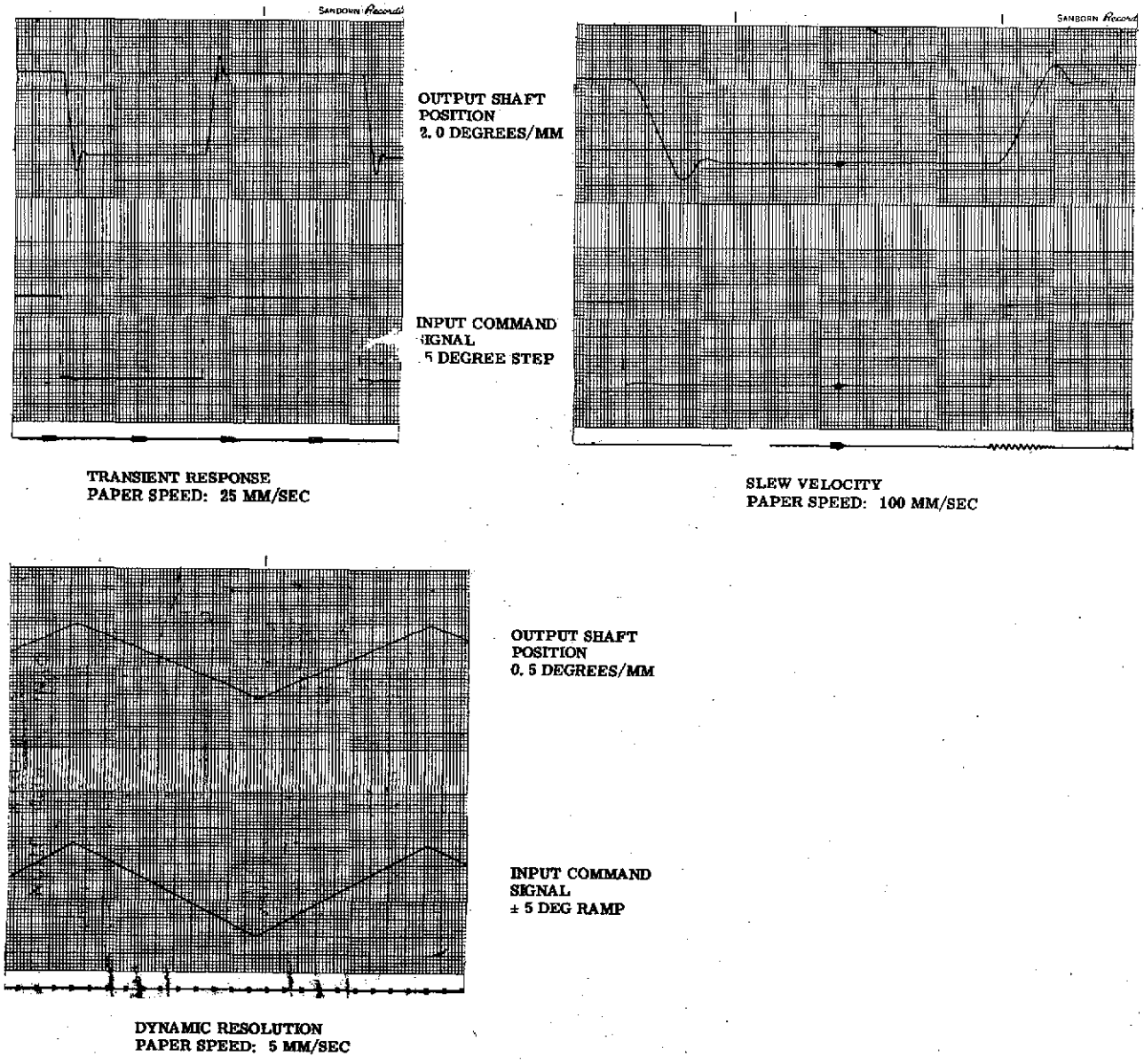


Figure 3-13. Dynamic Resolution, Transient Response, and Slew Velocity for Test Conditions (See Table 3-4)

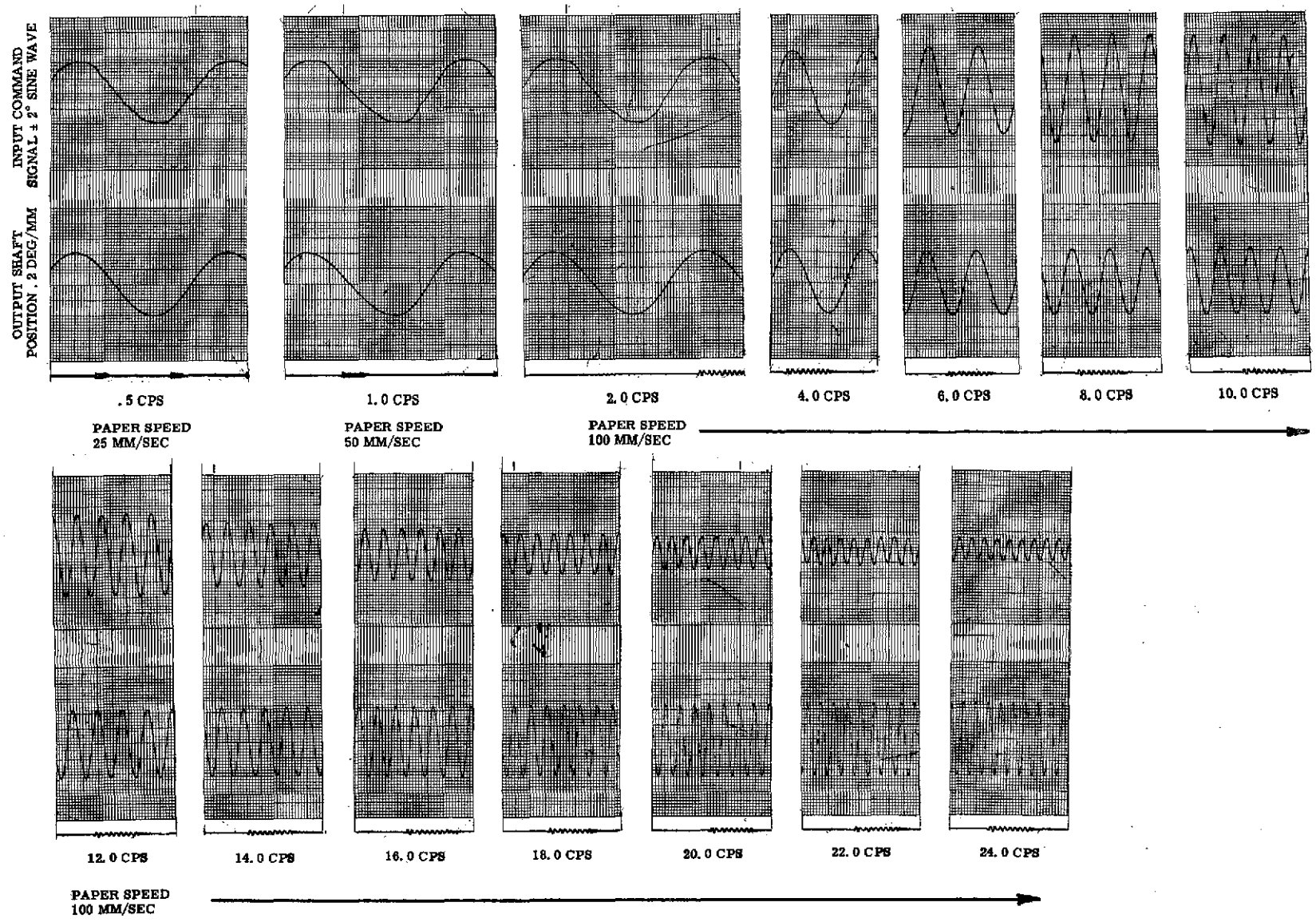


Figure 3-14. Frequency Response for Test Conditions (See Table 3-4)

APPENDIX A

PERFORMANCE CRITERIA OF TPCV ACTUATOR

The actuator has been tested against the following performance criteria.

A. Slew Velocity. Under loaded conditions, the slew velocity shall be 360°/sec, minimum.

B. Dynamic Resolution. The resolution of the actuator shall be ± 0. 5 degrees from the ordered position when the actuator is driven with a one degree per second ramp input command signal at 0. 05 CPS.

C. Frequency Response. The response of the actuator to a sinusoidal input signal of ± 2 degrees amplitude shall approximate a second order system with a break point at a nominal 8 CPS with a 0. 5 damping ratio minimum.

D. Transient Response. The response of the actuator to an input step amplitude equal to 45 degrees angular stroke shall be such that 62% of the corresponding output level shall be achieved within 0. 12 seconds.

The overshoot, following a transient disturbance to the actuator input shall not be greater than 20% of the ordered output level.

Following a transient disturbance, the output position shall be restrained to within ± 5% of the ordered change in position within 0. 3 seconds.